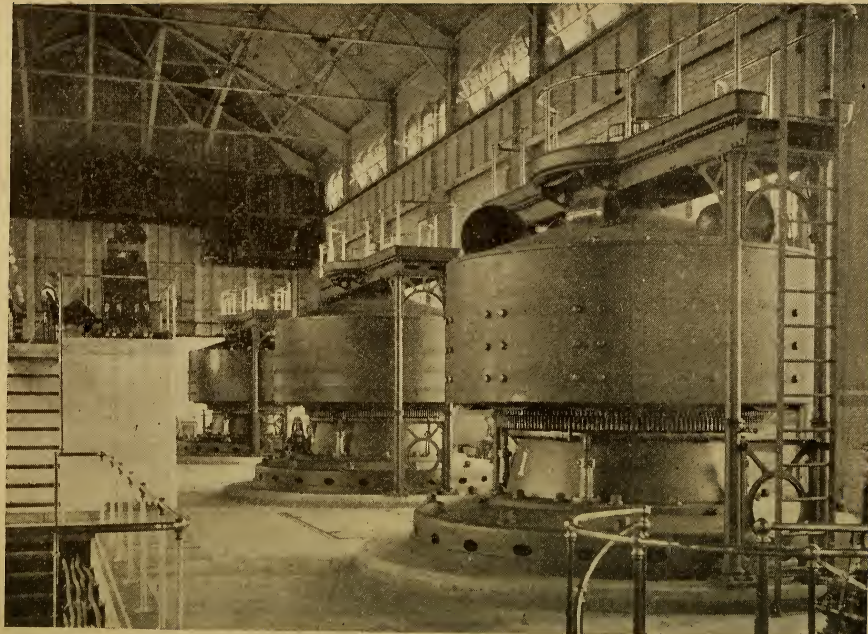
ectricity and Water=Power

Replogle



Interior View of the Niagara Falls Power Company's Generating Station, Showing Three Westinghouse 5,000-Horse-Power Alternators.—(From a Photograph taken in June, 1896.)—See page 126.

ELECTRICITY

AND

WATER POWER

AND THEIR

INTER-RELATIONS

A POPULAR TREATISE

DESIGNED TO HELP THE BUSINESS MAN, THE MECHANIC AND THE STUDENT TO FORM RELIABLE CONCEPTIONS AS TO THE FUNDAMENTAL PRINCIPLES OF ELECTRICITY AND WATER POWER

By Mark A. Replogle, Engineer

ILLUSTRATED

PUBLISHED BY
ELECTRICAL REVIEW PUBLISHING CO.
Times Building, New York
1896

PRESS OF
THE JAMES KEMPSTER PRINTING CO.,
NEW YORK.

CONTENTS.

PREFACE.

These articles are not designed as an engineering work, and it is not claimed that the principles set forth in them are identical with those of the most advanced thinkers.

To become conversant with any subject, one must have conceptions or clear-cut mental pictures that he may depend upon and feel to be reliable and true; and, since the forces we call "electricity" and "power" can not be seen, except by mental vision, it follows that no two minds have the same conceptions, as no two minds are alike.

The suddenness of the advent of electrical appliances has prevented many who are perfectly able, but engaged in other pursuits, from acquiring a knowledge of the fundamental principles by which electrical

phenomena are explained. The works of the engineers immediately plunge into the "meaningless" formulas of mathematics, which serve only to make these principles more mysterious.

The wish of the author is to put these principles into plain language, and in such a light that the busy man, the mechanic, and the beginner can form conceptions that will bear them out in reasoning or in making general calculations.

If he succeeds in dispelling the cloud of mystery that prevents many from seeing clearly the causes of various phenomena in the electrical and power world, so that even a few will be saved weeks and (as in his own case) months of perplexing difficulties, he will feel that his work has accomplished its purpose.

THE AUTHOR.

New York, October 1, 1896.

CHAPTER I.

ELECTRICITY.

The material universe contains a never-varying quantity of electricity, and each atom of matter inherits by the laws of nature its share, depending somewhat on the nature of the matter itself. If every atom of matter contained its portion at any one time, no electrical phenomena could be seen or discerned at such time.

All motion of electrical force is regulated by the law of supply and demand. All motion in nature is the result of forces seeking rest, a running down hill, as it were, stopping when the forces are equalized and balanced. But the forces of nature are so intermingled and so overlap each other that, while one force is finding an equilibrium, or state of rest, it disturbs other forces, which in turn

seek rest, and disturb still other forces. Thus in nature comes all motion—that of the air, of steam, of the clouds, of the streams, the lightnings, and of the flow of electrical currents—and the work of the true student of nature is to find the relation that the forces bear to each other.

The field is infinite, and but few of the pebbles have been gathered.

Electricity is not and can not be manufactured, as some suppose, but can simply be put in motion through conductors or wires. Thus currents are created, but not electricity. The flow is the result of an electric vacuum at one end of the wire and a pressure at the other end, but the two ends of the wire in practice are attached to a battery or dynamo, as the case may be. The battery and dynamo are then nothing more than electrical pumps. The wires are pipes that are always full, because they are material, and of such a nature that the electricity can easily pass from

atom to atom when put under pressure.

Some kinds of material have such an arrangement of their atoms that the electricity, even under great pressure, can not readily flow from atom to atom. Such materials are called insulators, and are used to keep electric currents within bounds; yet each atom of the insulating material contains its share, or will draw slowly from others until it does. Currents can be created in metallic circuits with less pressure, hence less power, than in other kinds of material.

There are, however, different degrees of resistance in the metals, and in commercial electricity the metal that will carry the most electricity for its cost in money is nearly always employed. Copper has this quality, hence it is used more than others. Iron has six times the resistance of copper—that is, it would take six pounds of iron to carry the same quantity of electricity a given dis-

tance that one pound of copper would; but one pound of copper wire costs less money than six pounds of iron wire, so copper is used.

CHAPTER II.

WHAT IS ELECTRICITY?

This is the question that very naturally presents itself to the minds of those who see the phenomena, but up to the present no man knows, or, at least, no one has been able to put forth a theory that will satisfy our advanced thinkers. The man who satisfies the world as to what it is will have climbed to heights unreached by Newton or Bacon.

We have no sense that can directly detect it. We can see the effects of it, also hear, taste, feel, and smell effects of it, but the force itself can only become an entity as it appeals to us through our secondary or reasoning powers. A conception of this entity must be formed by each individual for himself, and his mental picture

of it is a product of the facts placed before him and his imagination.

Electricity is probably a condition or property of matter, but the writer prefers to consider it in all its bearings and relations as a fluid or material—a highly elastic material—not affected by gravity or centrifugal force, and having no inertia or momentum.

It is so subtle that it pervades all material that appeals to our senses, but the ever-changing forces of nature in unwinding themselves shift it about, causing here a pressure and there a tendency to a vacuum, keeping quantities of it in motion all the time. Man has discovered how to put it in motion, and how to make it perform work in its efforts to find rest, and on these discoveries are based all of the electrical sciences.

Electricity in its natural condition is passive; it only becomes active when some exterior force is brought to bear upon it, and can only give

out the amount of power or energy put into it; hence it is only a means of transferring energy from one point to another. There is and can be only one kind of electricity. The different names, such as "static," "frictional," "galvanic," "thermo," "dynamic," etc., have arisen through different men viewing electrical phenomena from different standpoints. The terms "positive" and "negative" are used, but are sometimes misleading to the beginner.

An atom of material is only positive when it contains more than its share of the fluid, for then it is trying to supply its neighbors with the surplus. If an atom does not contain its share, it is negative, and proceeds to draw from its neighbors, and does so until an equilibrium is established. Positive indicates a surplus, or pressure, and negative an absence, or vacuum.

CHAPTER III.

CONDUCTORS.

Electricity is governed in its flow by well known laws. A river will sometimes run many miles around a mountain rather than run one mile through it. The reason is that the mountain is composed of material that it can not readily pass through, yet, if it came to the mountain with such force that the earth and rocks would give way before it, it would pass through. The same law always holds good in electric currents.

Gravity is the force that causes the river to flow from the mountain tops to the ocean. The battery and dynamo in like manner force the fluid through the wires.

The air and other insulating ma-

terials are the impenetrable mountains and the wires are the valleys. Electricity, then, always takes the course of the least resistance, no matter how far around it is, and in case of a battery or dynamo, the same electricity goes around and around through the pumps as long as there is a vacuum at one side and a pressure at the other. The quantity depends on the pressure and the resistance or holding-back power of the wire.

The writer expects to be criticised on his views of the elasticity of the electric fluid; but scientists have clearly shown us that, as in the case of the Leyden jar, the fluid can be drawn from one piece of material and deposited in another, and what is left is equally distributed throughout, yet they claim that it has no elasticity; but, as it has no inertia, its action in all cases is the same as that of material that is inelastic. The obstruction, or resistance, of the wire to the passing current causes heat,

the same as would be caused by any material passing through other material.

CHAPTER IV.

TABLE OF CONDUCTIVITY.

The conductivity of metals is determined by their inherent or natural resistance to electric current. The amount of current that will flow under a given pressure depends entirely on the specific resistance of the material through which the current is to flow; and a change in temperature changes the resistance in various materials. To be exact, in speaking of resistance, the temperature should always be known.

The following table will give a general idea of the conductivity of some of the common metals at a temperature of zero, centigrade thermometer. Silver having the highest conductivity, is rated 100. Impurities also change the conductivity, and in

the table the metals are supposed to be pure:

Silver	100.
Copper	99.9
Gold	80.
Platinum	18.0
Iron	16.8
Tin	13.1
Sodium	37.4
Aluminum	34.
Zinc	29.4
Cadmium	23.7
Brass	22.
Potassium	20.8
Lead	8.3
German silver	7.7
Antimony	4.6
Mercury	1.6
Bismuth	1.2
Graphite	0.07

NOTE.—Glass is called an insulator, and compared in the same way would rank at about 0.0000000000000157.

It will be noticed that aluminum will conduct about one-third as readily as copper, also brass about one-fourth,

iron about one-sixth and German silver about one-thirteenth as readily as copper. Glass conducts so poorly that it can be used where the electrician wishes to prevent a flow of current. Other common insulators are rubber, paper, fiber, gutta-percha, wood, wax, cloth, etc.

CHAPTER V.

MAGNETISM.

Magnetism is always found where there is any electrical phenomena, and on account of this has caused much confusion in the minds of students. In one sense it might be considered the only avenue through which electricity has any power value to man. Magnetism is not electricity, but it is incident to it, and always bears a certain relation to it. If an electric current is in motion, lines of magnetic force are passing around the current (in reality, running at right angles to the current). If the current of electricity should change to the opposite direction, the lines of magnetic force immediately reverse, keeping at right angles to the current.

Lines of magnetic force are noth-

ing more than rows of atoms polarized; that is, arranged in regular order. It will be remembered that each atom of matter is supposed to have a positive and a negative pole, and when the atoms of any portion of material are polarized it becomes a magnet. So magnetism is nothing more than a condition of the material surrounding an electric current, and it is not electricity. We only know that this is a fact; but none can tell whether it is out of respect to the passing current or whether some unknown law compels lines of magnetism to run around the passing current.

The work done by electricity is done by the magnetism surrounding the passing current and not by the electricity itself. If lines of force or magnetism are caused to run around a wire which is a part of a complete circuit, the electricity in the wire will move in one direction. If the lines of force were to move in the

opposite direction, the electricity in the wire would also move in the opposite direction. This principle is the foundation of all dynamos.

Let this be understood : A *wire* or any *conductor*, having a *current* of electricity passing through it, has *lines* of *magnetic force* passing *one way* around it, and the *number* is in the *direct* ratio to the *quantity* of current passing through the wire. This magnetic effect is strongest close to the wire, and decreases inversely as the square of the distance.

A permanent magnet has lines of magnetic force continually passing through it. It is possible that, if all were known pertaining to it, a continuous current of electricity might be somewhere found that makes or keeps it a magnet, or else the magnet may be keeping up a current somewhere.

CHAPTER VI.

ARC ELECTRIC LIGHTING.

Having dwelt at some length on the principles of the flow of currents, the remainder of the phenomena attending such flow becomes easy to understand, and we will begin with lighting and display the principles of all the well-known phenomena.

If electricity were forced through material that offers a high resistance to it, the mechanical power required to force it through such resistance would be converted into molecular motion or heat. If the area of resistance is small, the heat is intense, and becomes more intense as the quantity of current increases. Air offers a very high resistance to currents, hence becomes white-hot when electricity passes through it. (A cur-

rent passing through air is called an arc.) If the ends of the wire were used to cause the arc, they would melt from the excessive heat and could not be regulated properly, hence carbon pencils are used.

The pencils do not melt, but shell off in a kind of carbon vapor, and the friction caused by the current passing through the air heats it and the carbon points to a white heat, emitting light. Arc lights are made from both continuous and alternating currents. The former flow in one direction only, and the latter are currents that are reversed many hundred times in a minute. (Since electricity has no inertia, it can be reversed very quickly, and a reversing current is called an alternating current.)

The small machinery in an arc lamp is for regulating the distance between the carbon points as they wear off. A two-thousand (2,000) candle-power arc lamp requires a trifle over one horse-power of mechan-

ical energy to run it. Arc lights usually are connected in series; that is, follow each other in the same wire, and the pressure must be increased as each new lamp is put into the circuit.

CHAPTER VII.

INCANDESCENT ELECTRIC LIGHTING.

The incandescent light is caused by making a small portion of the wire so small that it becomes heated by the current. Nearly all of the materials in nature will oxidize or burn when white-hot, in ordinary atmosphere, but the commercial incandescent lamp has its contracted or small conductor in a glass globe, from which the oxygen has been removed, and the filament, as it is called, is nothing more than a carbonized thread of some strong fiber, such as bamboo or linen.

Since the oxygen is gone from the globe, the filament can not burn and remains intact until weakened by scaling and crystallization. Both continuous and alternating currents are

used for incandescent lighting, and the lamps are usually in multiple; that is, each is fed from the same feed wire, and each receives the full pressure of the dynamo or transformer. In some cases these lamps are used in arc circuits, but there must be enough of them in multiple to allow the whole current to pass without destroying the filaments by over-heating. From eight (8) to ten (10) sixteen-candle-power lamps can be had from one mechanical horse-power of energy. Some manufacturers claim more.

TRANSFORMERS OR CONVERTERS.

The electrical engineer, while scheming to transmit energy as cheaply as possible, must keep in mind the safety of the people who use it. It is a fact that the higher the pressure used to convey energy through a wire, the more can be carried on a given sized wire, but it is also a fact that the higher the press-

ure, the more dangerous does the wire become. So, by the use of the alternating current and transformer, high pressure and safety are both possible in the same installation. The high-pressure current is brought to a transformer outside of a building, and, after passing around the primary coils, returns to the dynamo.

Inside the primary coil is a secondary coil of larger wire, and both coils are inclosed in laminated soft iron cases. A new current is generated in the secondary coil of lower and safe pressure. This supplies the lamps in the building. (The new current is caused by induction, and is also an alternating current.)

Transformers can be constructed to step up to higher pressure, as well as down to lower. There is no gain or loss of energy save that due to friction, and if the pressure is stepped down, the quantity increases; if stepped up, the quantity diminishes, leaving the same amount of energy.

These phenomena are caused by exceeding high pressures and small quantities of electricity. They may be seen to a small extent by presenting a metallic point to a heavily loaded belt driving some machine. It can be seen best after dark. In such a case it is an intermittent current. Nikola Tesla is astonishing the world by this kind of phenomena from high-potential, alternating currents, and all eyes are turned towards him for facts in this line.

CHAPTER VIII.

ELECTRIC POWER.

It has, no doubt, been noticed that lighting by electricity is a result of impeding the *electric current* by resistance; but power is the result of impeding the *magnetism around the current*. (This, in turn, impedes the current.) Work or power is acquired from the current, only by the use of the electro-magnet.

An electro-magnet is simply a concentration of the magnetism of a current through a long wire. If one inch of a conducting wire with a given current throws off a certain number of lines of magnetic force, 100 inches will throw off 100 times as many. So the 100 inches may be wound on a piece of iron called a core, and the full amount of mag-

netism will be concentrated in the ends of the core. If the iron is soft it ceases to be a magnet as soon as the current stops, and becomes a magnet as soon as the current passes again.

Here is the foundation of all our telegraph systems. The operator with his key starts a current through the distant magnet. It in turn attracts a small piece of iron with a "click," and when the current is stopped by breaking the circuit a spring pulls the piece of iron away with a "clack." Combinations of clicks and clacks are letters and words.

The force with which an electromagnet (properly constructed) attracts soft iron has led many searching minds to an idea of transferring power in a manner similar to the telegraph; that is, by wire. This idea has been experimented upon during the past few years to such an extent that it has been proved beyond

doubt that energy or power can be transmitted great distances by the use of electric currents and with less loss than by any other means. Let it be understood, however, that there is no power in electricity except that put into it. In other words, the wire circuit is dead until we put the electricity it contains in motion by some external power or force. This can only be done by or through the means of magnetism, when our energy is applied in the form of power.

The machine that is constructed for the purpose of mechanically wrapping magnetism about or around the conducting wire is called a *dynamo* by the electrician, and in doing so it consumes power in the same ratio that the current is allowed to flow through the wire, plus the friction or loss in heat. The battery puts the electricity in a wire circuit in motion by means of chemical action. One of the results of chemical action is electrical pressure, and if a wire is

connected to a part of a battery that is under electrical pressure, and be continued even for a great distance, any point in this wire will be found to be under electrical pressure. If this wire is returned to the battery and connected to the part of it that is negative, or has a tendency to an electrical vacuum, then a current will flow as long as the chemical action continues in the battery.

The electric current generated by the dynamo is in all respects like the current generated by a battery; that is, a continuous dynamic current is identical with a battery current. The distant telegraphic instrument then by the proper remodeling becomes a machine that will take power from a passing current, and the part that only vibrated in telegraphy is placed on axles, and revolves when a current is passing through it. The instrument in this shape is called a *motor* by the electrician.

CHAPTER IX.

THE ELECTRIC MOTOR.

The motor is simply such a combination of electro-magnets as will (through the laws of attraction) cause one circular magnet (called the armature) to rotate on its axis, when the current of electricity is passing through all of them. Although the armature revolves, it is provided with means that allow the passing current to enter it and flow around it longitudinally many times in its circuit, and then flow out and back through the return wire to the source of energy or electrical pressure.

The portion of the motor that keeps this current in the proper wires at all times is called a *commutator*, and is, in some respects, a very complex portion of a motor or dynamo.

To define it in simple words, we might say that a commutator is an automatic system of switches that directs the flowing current into such wires of the revolving armature as are necessary to cause the magnetism of the armature to bear such relation to the magnetism of the field magnets that the effect is motion of the armature.

The motor can be built to run with alternating and polyphase currents as well as continuous currents. (A polyphase current is nothing more than a compound alternating current, and requires more than two wires to carry it.) Motors that are especially designed for polyphase currents are called induction motors and do not have commutators. A separate and distinct current is induced and kept within the armature. To this current is due the magnetism necessary to cause the revolutions. A high efficiency is claimed. Motors may be made to run in synchronism, or keep

step with alternating current dynamos. Motors may also be built to run from intermittent currents.

DYNAMO ELECTRIC MACHINE.

The dynamo is nothing more than a motor running backwards, and the power applied to it forces the electricity around through the wire, to be impeded for light, or have its magnetism impeded for power. (As we have said before, these operations impede the current.) While the magnetism and current always travel at right angles to each other, they, however, are a kind of Siamese twins that can not be separated.

The actual duty of the dynamo is to cause, in a mechanical way, lines of magnetic force from the field magnets to pass around the wires on the revolving armature, and the electrical pressure, endwise in these wires, causes all the electricity in the circuit to move. The greater the pressure the faster the current. Dynamos are

constructed for continuous, alternating and polyphase currents, also for high and low pressure.

The dynamo will be treated of more fully under the head "Power Transmission."

CHAPTER X.

BATTERIES.

Batteries are of many kinds, but all of them are simply electric pumps, and the pressure is due to the chemical action. There are two classes, however—open circuit and closed circuit. The open-circuit battery is so called because it can not maintain its initial pressure for any great length of time; hence the circuit must remain open when not at work.

The closed circuit battery is usually called a gravity battery, because gravity causes the changes that allow it to maintain a constant pressure. This last battery is employed very largely for telegraphy.

STORAGE BATTERIES.

Storage batteries do not store electricity. A dynamic or other continu-

ous current in passing through them causes a chemical action to take place. When this current is stopped the contents of the cells tends to change to its original condition, and while doing so the battery becomes an electric pump, as any other battery; thus. instead of supplying chemicals, as is necessary with ordinary batteries, they are formed by the dynamic current passing through the cell.

On account of their great weight and disarrangement by the motion of the car, these batteries, or accumulators, have not yet proved a success commercially for driving street cars. The only real storage of electricity is in the principle of the Leyden jar. In this case the electricity is actually taken from one portion of material and deposited in another portion. The quantity thus stored is so limited that it is of no value commercially, and amounts to little more than a plaything.

Accumulators, however, are of real value in central stations. By the direct system of power or lighting a plant must be maintained equal to the greatest required output; but by the use of accumulators a small plant running all the time at good efficiency can accumulate energy enough to permit a heavy output during the busy hours.

ELECTRIC HEAT.

Heat is derived from electric currents in the same manner as light, by impeding the current with resistance. A kind of wire is used that offers a great deal of resistance; this is inclosed in porcelain, asbestos or other insulating material; and the greater the current the greater the heat.

For general heating this is too expensive. The best steam engine can only utilize fifteen per cent (15%) of the energy of the fuel. The dynamo can give a little over ninety per

cent (90%) of this; but for cooking, ironing, etc., it is often cheaper than fuel. Cheap water power will be used extensively for generating current for electric heating in the future.

CHAPTER XI.

ELECTRICAL UNITS.

The measurement of electrical currents is, perhaps, the most difficult of all measurements to understand, yet without some means of determining the quantity of force and the quality of force, electricity would be of no value in the commercial world.

Electricity was known hundreds of years before it became known in the power world, and it was only after Ohm had demonstrated that it could be measured correctly that it was employed in commerce. The little formula called "Ohm's Law" will perpetuate his name, although to the average reader it may be meaningless. To state it in its simplest form it is: $C = E \div R$; meaning, the current

equals the electro-motive force divided by the resistance. We will give below a few of the common units of electrical measurements.

The *volt* is the unit of pressure, or electro-motive force (E. M. F.), and is equal to a little greater pressure than that exerted by a common gravity cell. The volt is represented by "E" in all electrical calculations.

The *ampere* is the unit of current strength and denotes the rate of current flow past a given point in the wire. The ampere is about equal to the rate of flow through a sixteen (16) candle-power lamp burning under fifty-two (52) volts' pressure. In electrical calculations the ampere is represented by "C."

The *ohm* is the unit of resistance or holding back power of the wire. Resistance is the bane of the mechanical engineer, but without it electricity could not be controlled; hence would be of no value. One thousand feet of copper wire No. 10 (Brown

& Sharpe) gauge has about one (1) ohm resistance, but if the 1,000 feet were twice as thick, that is, if the area of its cross-section was twice as great, it would only have one-half ($\frac{1}{2}$) an ohm resistance, and the less the resistance the greater the flow of current under a given voltage. So the electrician regulates the flow of currents entirely by the resistance, when the dynamo pressure is fixed.

The ohm is represented by "R" in electrical calculations. You will now notice, by the formula, that the number of amperes' flow can be determined by dividing the number of volts, or dynamo pressure, by the number of ohms' resistance in the wire. Also, if any two of these quantities are known, the third can be easily calculated.

The *watt* is the unit of energy and is equal to $\frac{1}{746}$ of a horse-power (746 watts equal one horse-power). If the volts' pressure of a dynamo is multiplied by the amperes' flow, the

product will be watts. Divide the number of watts by 746 and the quotient will be mechanical horse-power. The watt is represented by "W."

The *coulomb* is the unit of quantity and is the amount that flows past a given point in a wire, in a second, with a current strength of one ampere. It is represented by "Q."

The *joule* is the unit of heat, and is found by multiplying volts by coulombs. Represented by "Wj."

The *farad* is the unit of capacity and is used in calculations where residual effects are considered. Represented by "K."

The *henry* is the unit of self-induction, and is considered in magnetic calculations. It is represented by "L."

The *dyne* is the absolute unit of force and is the basis of all calculations in electrical and mechanical forces. It is the unit from which all calculations of energy diverge. The

dyne is the quantity of force required to start a body, equal in weight to one cubic centimeter of distilled water at a temperature of four degrees centigrade, to a velocity of one centimeter per second. One horse-power (H.-P.) is equal to about 7,464,388,525 dynes in the latitude of London.

Our treatment of electrical principles has been condensed and very general. If the reader wishes details he must consult text-books or engineering works.

CHAPTER XII.

FORCE.

Force, motion and power hold certain distinct relations to each other, but, on account of inaccurate thinking, they often form a kind of mixture in our mental conceptions. Force might be regarded as pressure, or ability to put material in motion. We have no sense that can detect force except by its action on material. Its effect only can appeal to our senses; hence our reasoning powers. In a few avenues man has learned to control it. He can store it and release it only by bringing other forces to bear upon it.

Nature has supplied forces in infinite quantities and numbers. These forces are in continual warfare with each other. A disregarding man pauses

until he gets a faint conception of some of them, employs a few of these to accomplish his selfish ends, and stands before his less observing brethren a philosopher.

As before said, force is the ability or pressure that can give motion to material. Motion is the result of force applied to material, but power is sustained motion, the result of force continually applied to material; that is, the time of the motion must be considered in reckoning power.

The ordinary unit of power is the foot-pound. It is the amount of power represented by one pound of material acted upon by the force gravity in moving one foot toward the center of the earth in one minute of time. The ordinary definition of foot-pound is the amount of power required to lift one pound one foot high in one minute; 33,000 foot-pounds are called one horse-power (H.-P.).

There are several kinds of motion. That which we are most familiar with is continuous motion; that is, masses of material continuously changing position. There is another motion of material that we wish to call special attention to. It is the vibrating motion of the molecules, or molecular motion.

We may take a piece of any solid substance, say iron, at any ordinary temperature, and if we could discern with the physical eye, we would learn that its molecules (while each seems to be gripping its neighbor tightly) are, in reality, bounding back and forth like fractious colts. The mass, or aggregation, of molecules may be in a state of rest, but if the energy stored in it, in the shape of molecular motion, were converted into continuous motion or power, there would be enough power to move the piece of iron some distance.

If we bring some outside force to

bear upon our piece of iron, causing such an increase in the molecular motion that we can perceive it by the sense of feeling, we call it warm or hot. If we increase this molecular motion by external forces to a point where the molecules lose their tight grip on each other, our iron is in liquid form. If we continue to increase the molecular motion until the molecules in their rapid motions crowd themselves apart, forcing each other into surrounding materials, we say it has turned to gas. What is true of iron is true of all solids.

The forces of nature in battling with each other give molecular motion to material. The molecular motion or heat of the material of the earth is the direct result of the ever-battling forces of nature.

How kind of nature to maintain a temperature that man can live in. A hundred degrees warmer or colder, on an average, would make the earth barren. To be sure the heat of our

surroundings or climate varies, but it is in the ratio that one set of forces gain for a time, an advantage over their antagonists.

POWER.

Power is nothing more than the molecular motion of material converted in a mechanical way to a continuous motion of material. Work is simply power or continuous motion of material being changed into molecular motion or heat.

When we have energy in the shape of power, we shift it around through our various machines. We cause it to weave, to spin and to grind. At each point of operation, heat or molecular motion is created, and the power is gone, to be ours no more. It simply rejoins in the battles of the contending forces.

Man finds force in a crystallized or static condition, as in coal or fuel. He releases it by starting it to vibrate so rapidly that the carbon can unite

with the oxygen of the air (or burn, as we commonly say), and his steam engine is nothing more than a machine that converts molecular motion or heat into continuous motion or power.

Continuous motion or power is an unnatural motion ; hence, all continuous motion sooner or later reverts to its original form—molecular motion or heat. All the wonderful things in mechanics, and we may say physics, are performed by motion in a continuous form reverting to motion in a molecular form, or vice versa. Continuous motion can not be maintained without a continuous source of supply ; but molecular motion never ceases.

Perpetual motion, then, can only exist when some never-failing fountain of supply can be tapped. The forces that revolve the earth on its axis might be utilized for turning machinery, but, in such an event, the days and nights would become longer and the climate would be warmer for

a time in consequence of the extra amount of continuous motion of the earth being converted into heat or molecular motion.

We have dwelt at some length on motion in the form of power and heat, but we wish to take up water power and make it clearly understood. We wish to show that water power is the cheapest source of energy, why and how it can be used to perform our labors and supply us light and heat at any and all places that we may desire them.

CHAPTER XIII.

WATER POWER.

Water power, so called in ordinary conversation, is power derived from gravity, hence is gravity power.

It is well known that a head or vertical column of water will at its lower level exert a pressure in direct ratio to its height. This pressure is the effect of the force – gravity—and will cause the water to spout through an opening at a velocity equal to the same velocity that a body of the same specific gravity would acquire if it had fallen a distance equal to the height of the head.

Hence, to determine the spouting velocity of a water fall or head, the engineer employs the "law of falling bodies." It is always necessary to know the spouting velocity of water,

because gravity exerts all its force in spouting water and has found its equilibrium in doing so.

The problem for man now is to devise a machine that will stop the water that gravity has spent its force upon, and thereby collect the power that has been generated by giving motion to the water. Such a machine is called a water-wheel. The steam engine converts the molecular motion of the steam into continuous motion or power, but the water engine transfers the continuous motion of the water to the shafting, hence is the simplest in operation.

Reasoning from the facts that the spouting velocity of a constant head is always the same, and that the wheel gets its power by stopping the water that gravity has put in motion, it follows that there can be only one correct speed at which the wheel can get the highest amount of power from the water. That is, the ratio of wheel-speed to water-speed must

always be maintained, or a decrease of efficiency will occur, which will be detrimental to both power and its government. This ratio varies in the different wheels, owing to the difference in principles involved, or difference in construction.

It will be noticed, however, that water-power can only be found in the moving water, and when it is found in the revolving shafting, it is water-power no more—simply power. The source of supply may be called water-power, but, if we trace it back to first principles, we find the source of this energy back in the molecular motion or heat of material.

The real source of this, as well as that of all other mechanical energy, is in the sun. The heat caused in material, in consequence of its intercepting the sun's light or energy, shakes, as it were, water into such exceedingly small particles that they fill the small spaces between the molecules of the air.

The sun's energy creates the greatest molecular motion in the most dense materials. Hence the solid substance of the earth's surface becomes more heated than the air. These, in imparting their vibration to the surrounding air molecules that hold in suspension the water particles, cause the air molecules to become lighter or less attracted by gravity. The heavier and cooler air molecules are drawn under them by gravity, wedging them up, as it were, away from the earth's surface. The air pressures and the vacua, brought about by the unequal heating of the surface of the earth, cause these freighted molecules of air to move.

If this water-laden air were never brought under the action of other forces, it would forever retain its moisture. But by some sudden change in temperature, and thereby in pressure, it is forced to release its load, which again, through the action

of gravity, falls in the shape of rain to the surface of the earth, giving back the same amount of heat that was required to expand and elevate it. Each molecule of water will continue its motion according to the effects of gravity, until it can find a support or rest, or, as we commonly say, its level; giving out energy in the form of power or heat until its descent ceases.

The molecule of water, then, is simply an agent in the hands or influence of the warring forces of nature; and when the force gravity has the better of it, and is converting its motion or power into heat, man steps in with his water-wheel and requires gravity to perform labor or work, before he will release its slaves, the water molecules; and the extreme amount of work that can be had from the molecules of water is equal to the amount of energy that was required to lift it to the height of the head, after subtracting the

various losses incurred through the operations of its descent.

The spouting velocity of water, due to any head, may be found by multiplying the square root of the head in feet by 8.025, or one-fourth (¼) the velocity a body will acquire in falling one second. This product will be feet per second. *Example:* What is the spouting velocity of a 16-foot head? The square root of 16 is 4, and 4 multiplied by 8.025 equals 32.1 feet per second. The velocity per minute equals 32.1 multiplied by 60, or 1,926 feet.

To determine the actual power represented by a waterfall, we multiply the head or fall in feet by the number of cubic feet flow per minute. Multiply this product by 62.5 and the product will be foot-pounds. If we divide this product by 33,000 our quotient will be the maximum horsepower. Subtract from this quantity the loss in carrying the water to the wheel and the loss in the wheel, and

the remainder can be relied upon as power for other purposes.

Example: How much power can be obtained from a 16-foot head having a flow of 6,825 cubic feet per minute? Answer: 16 multiplied by 6,825 equals 109,200. This product multiplied by 62.5 equals 6,825,000 foot-pounds. Dividing by 33,000 we have 206.8 gross horse-power. If we count 20 per cent loss in the wheel and five per cent loss in getting the water to the wheel, we can count on 75 per cent available power. Seventy-five per cent of 206.8 equals 155.1 net horse-power.

CHAPTER XIV.

WATER-WHEELS.

The simplest way to define water-power is to state that it is energy from the force gravity applied in giving continuous motion to material by means of or through the liquid medium, water.

Four distinct principles have been and are employed to take power from gravity by means of water.

1. By using the pressure and keeping the water confined. The same principle as is used in the steam engine.

2. By the direct action of gravity, as in the overshot wheel.

3. By impact or stopping the water that gravity has already put in motion.

4. By pressure or reaction, as exhibited in the Barker mill.

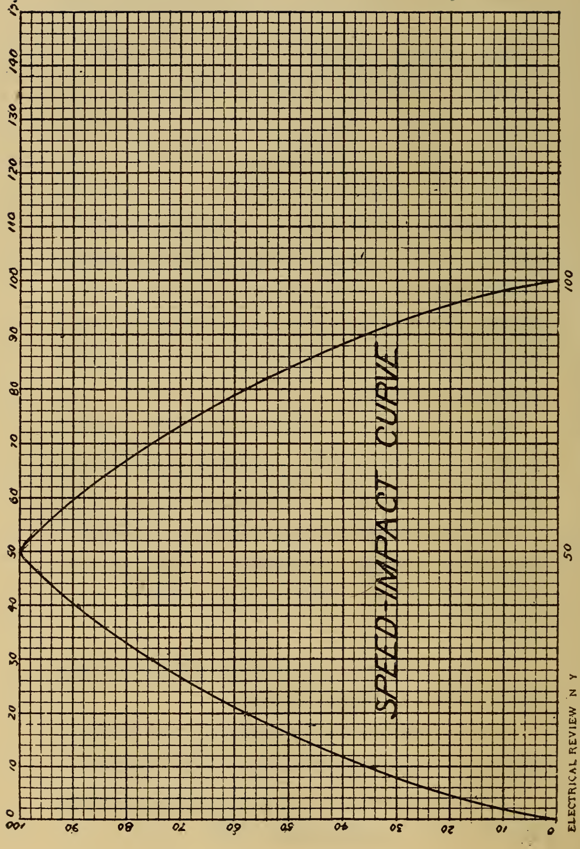


Fig. 1.—Speed-Impact Curve.

The first and second principles mentioned are practically obsolete, but from the third and fourth principles there are now being manufactured three distinct types of water-wheels, and many variations of each type.

We will here introduce some general curves that are intended to give the reader an idea of the relative velocity that various water-wheels should run. Note carefully that the horizontal distances represent velocity and that the vertical distances represent power. If these general curves are carefully examined, a fair idea can be had of the loss in efficiency of a water-wheel, due to running too fast or too slow.

In the following curves, it will be observed that the spouting velocity of the head is represented by 100 on the horizontal lines, and any increase or decrease will be considered as a like percentage of the spouting velocity. For example, 150 equals

150 per cent, or one and one-half times the spouting velocity of the water, and 66⅔ equals 66⅔ per cent, or two-thirds of the spouting velocity of the water. In the vertical line the maximum power a wheel can give is represented by 100, and any number less is a like percentage of the full power. For example, 50 equals 50 per cent, or one-half of the full power of the wheel.

Please note that the curve is based on the supposition that the water-wheel gates are wide open in each case, also note that the curve is general and may vary with the modifications of the wheel in question.

To determine the approximate efficiency of a water-wheel running at a given—say, 40 per cent – relative speed, place your pencil on 40 in the horizontal line of diagram pertaining to the kind of wheel in question and follow vertically until touching the curve; from this point move pencil in a horizontal direction until it

touches the side of diagram, where the power figures are, then note percentage of power. In this way the percentage of power can be determined in any speed the wheel may attain from standing, or zero, to its highest speed.

The highest relative velocity a wheel may run if not impeded by work can also be determined by noting where the curve ends. For example, see the impact curve. In this it will be noticed that the curve ends in the diagram at 100. This indicates that the wheel running empty with full head of water can run just as fast as the water moves. Please note that in speaking of the velocity of a water-wheel we refer to its circumference or periphery speed.

Note that speed of highest efficiency in the impact or impulse wheel is 50 per cent of the spouting velocity of the water. In actual practice it is about 45 per cent of the theoretic

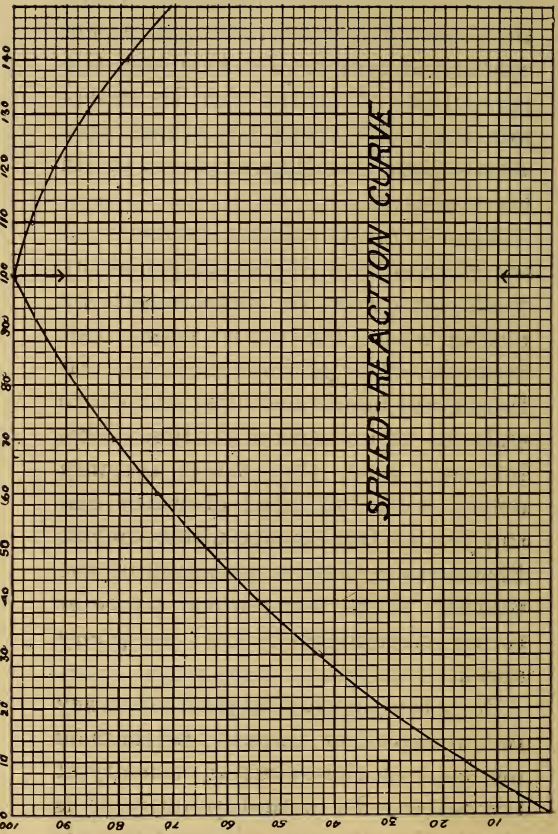


FIG. 2.—SPEED-REACTION CURVE.

spouting velocity of the head that drives it.

The reaction principle of getting power from water is seldom used in its simplest form, but, as combined with the "impulse" in the turbine, it is a most important factor in power getting. The amount of power that can be had from a wheel of this character can be found by finding the amount of pressure on the inside of wheel at orifice, after the outside pressure at orifice is subtracted. This difference in pressure (in pounds per square inch) must be multiplied by the area of orifice in square inches, and this product multiplied by the velocity (of the wheel at orifice) in feet per minute will give the foot-pounds of power. After the loss due to friction is subtracted the balance is available power.

Please note that the theoretic speed of this principle of wheel is a velocity equal to that due to the head driving it.

The turbine wheel is a combination

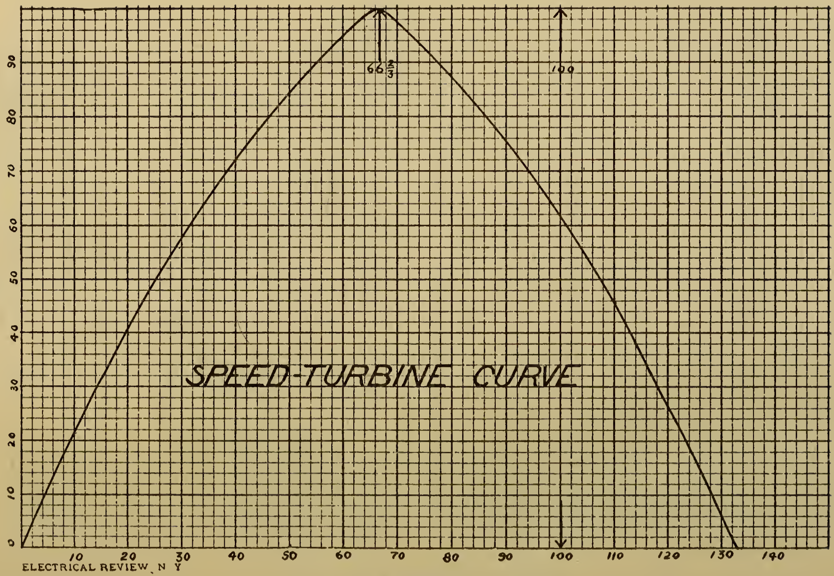


FIG. 3.—SPEED-TURBINE CURVE.

of the two foregoing principles, and its theoretic speed is less than that of the reaction wheel. This class of wheel in its actual construction is an impulse wheel at the beginning of gate opening, and a reaction wheel at full gate opening. To give its highest efficiency at all points of gate opening, its speed should be that of an impulse wheel at the beginning of gate opening, and increase with gate opening, approximating the speed of the reaction wheel at full gate opening. Since it is impractical to run machinery at variable speeds, the turbine manufacturer gives it a conventional speed; that is, a speed that he considers is the best average, usually a speed of from three-quarters to seven-eighths gate opening.

Please note the difference in the speeds of the three classes of wheels. The curves are based on the supposition that the three wheels are of equal horse-power and are driven

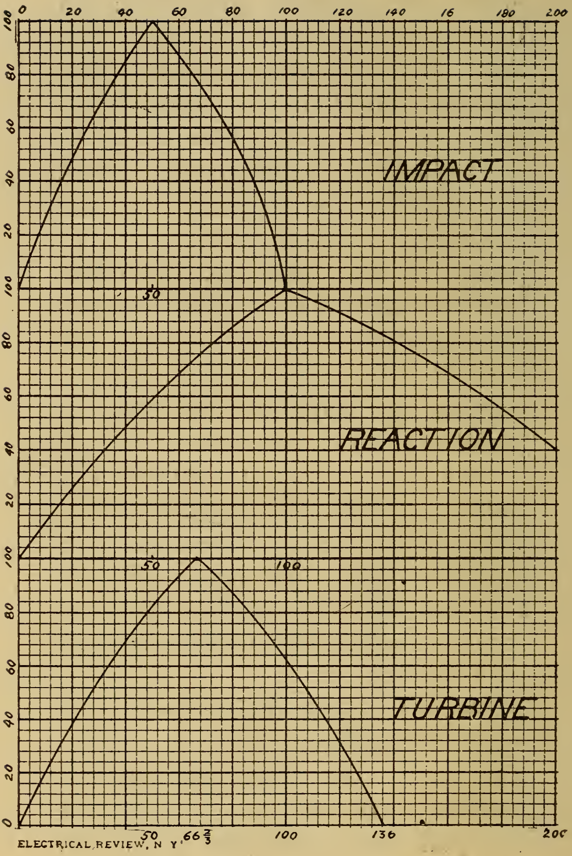


FIG. 4.—COMPARISON OF CURVES.

by the same head. The limits of speed of impulse wheel and turbine wheel are shown on the diagram, but the limit of the speed of a pure reaction wheel is determined only by the friction of wheel in revolving, or some load. It is also checked by the centrifugal power applied to the water that is passing through it, hence it may attain (without a load) a speed equal to several times that of the spouting velocity of the head that drives it.

These curves are made to assist the engineer having water-wheels in charge. They are the result of careful experience in running and governing water-power plants.

CHAPTER XV.

GOVERNMENT OF WATER-POWER.

It has been clearly demonstrated that water falls can turn dynamos. Scores of water falls are already harnessed, but this class of work is yet only in its infancy. To govern the wheels automatically and safely is a problem of grave proportions.

Water-power has been known and used longer than any other kind of power, but it is not so clearly understood to the masses as steam-power. This may be due to the fact that it has not played so important a part as steam in the affairs of commerce, and the reason is, it has to be developed where nature designed for it, while steam power is more flexible, and can be placed on the top of a mountain as well as at its base.

One of the great things to be desired in power for dynamos is regularity of speed, and it should be maintained under the varying conditions of load. Much time has been spent in devising machinery for this kind of work, and, while much has been learned, there are still some intricate problems to be solved. It might be said, also, that the matter of plant construction is in a state of evolution, and it is hoped that it will result in the development of ideas that will make water-power development more simple and efficient both in power and government.

The fundamental principle that makes water hard to govern is well known. A body at rest requires force to put it in motion; it requires more force to increase its motion, and if brought to rest again will give out as much energy as was absorbed to give it its maximum motion. The loss due to friction must always be subtracted.

The above operation is precisely what takes place in getting power from water. The water in the reservoir is material at rest. It has a slow motion in the flume or penstock; at the guides or nozzles, where it comes in contact with the wheels, it has attained a velocity approximating the spouting velocity of the head. At this point it represents the full amount of power that gravity can supply it with. In other words, the force, gravity, has established an equilibrium in giving motion to the medium, water.

The duty of the wheel is to bring the water to a state of rest, and in doing so it received the amount of energy that gravity expended in giving it motion. Practically the water must have some motion to carry it away from the wheel, and such motion of water is a loss of power.

Consideration will teach any one that if gravity is applying all its energy at one point of operation it

can not at the same time apply it at some other point; hence, if water is incased in wooden or iron flumes, the whole body must move when an increased quantity is required at the nozzles. The increased motion must come from the action of gravity on the equivalent vertical head, and since the effect of gravity is constant, it is plain that, if the power is absorbed in giving motion to water in the flume, it can not at the same time keep the same supply at the water-wheel.

The loss of time when power is required for heavy changes in load makes water exceedingly hard to govern, and has given an opportunity for a few specialists in this kind of work. They have gradually overcome difficulties and improved the construction and adaptation of governors until it is possible to get governors that rank favorably with steam. It is always advisable to take the matter of regulation of water-

wheels into consideration before a power plant is constructed, as many plants have been deprived of the best government by neglecting the matter until it was too late.

When large plants are constructed for commercial currents, the matter of government is more important than in private plants, and, since the tendency is to build direct-connected plants, it is highly important that the regulation be directed by reliable parties, expert in this line. Since there is less power wasted in a direct-connected plants, it is correspondingly harder to govern.

There have been some very important discoveries made in the line of water-wheel regulation in the past two years. It can be said that the subject has received more earnest attention, and that it has improved more in the last two years than in any one century previous. All this is due to the fact that power can now be transmitted electrically from the

water fall to the very heart of a thriving city, giving to various industries cheaper power than steam, and returning to the promoter and capitalist substantial revenues on their investments.

CHAPTER XVI.

DEVELOPMENT OF WATER-POWER.

The development of water-power has received a new impetus since it has been demonstrated that it can be transmitted electrically. The ideal way of the past was to carry the water from the falls or dam by means of a systematic series of canals. These were often arranged in a manner that would permit power to be distributed over a large area of factory sites.

Where a reasonably high head could be procured, the canals would have different levels. That is, the factories of one canal would discharge the used water into a lower canal. This canal served as head water for another series of factories, and so on until the lower level was reached.

The water power of Holyoke, Mass., Cohoes, N. Y., and Paterson, N. J., are good examples of this kind of development.

The objections to this plan of development are many, and we will enumerate a few of the most prominent ones: Cost of excavating canals as well as the cost of the land they occupy; cost of a multitude of wheel pits, wheels and power plants; the loss of the power necessary to carry the water through the long canals and penstocks. and the loss of the power necessary to turn an innumerable number of wheels and line shafts.

The ideal way of the present is to build at the water fall one power house, occupying very little land, one wheel pit and a few wheels—just enough to divide the power into economical units of distribution. The plant is further simplified by building wheels and dynamos to fit the water fall and adapted to each other; or, if other methods of trans-

mission are employed, a similar simplicity of development should be followed.

To get the best results in this kind of development, our leading water-wheel manufacturers should be consulted, also our leading dynamo builders or electric companies. They are fully alive to the requirements of this kind of development and have specialists for this class of work. The dynamo builder and the water-wheel builder should consult the specialist who constructs machinery to govern water-power, and he must build a governor to fit the dynamo, water-wheel, and water fall. It will require the three to make a perfect plant, and those having the most varied experience are often the most economical and reliable parties to employ.

CHAPTER XVII.

POWER TRANSMISSION.

The ordinary methods of transmission, such as by shafting, belting and cable, are so well known that we will not comment, except to say that they waste too much power for long-distance transmission; hence are not considered when the distant water fall is to be harnessed. There are, however, two kinds of transmission that are receiving the attention of our engineers—pneumatic, or air transmission, and electrical transmission.

Pneumatic transmission is purely mechanical, but offers some economical advantages that even electricity does not offer. There are conditions where this method could be employed with greater efficiency than electric currents. In cases where factories

are run by steam power the energy could be conducted from the water power in air mains, from which the engines could be supplied, saving to the factory the cost of motors and the other necessary changes.

If the supply of air was in any way limited, it could be allowed to pass through the engine boilers and expanded with fuel. We are told that fully 70 per cent useful effect can be had from fuel in this way, as compared with steam power, which limits the useful effects to less than 15 per cent of the energy that the fuel contains. There is, however, a great loss in compressing air and transmitting it, giving to electrical transmission an advantage, especially in long-distance transmission.

The success of long-distance electrical transmission is being demonstrated in various parts of the civilized world. A government experiment in Germany demonstrated that 200 horse-power could be trans-

mitted 109 miles with a loss of only 28 per cent. This is less than that sustained by many of our finest factories in transmitting power mechanically to remote rooms. The experiment at Niagara has demonstrated that power can be taken from water in large and economical units, and it will be demonstrated that the same power can be transmitted to Buffalo and sold with profit for less than steam power costs.

Electrical transmission is of three kinds, and may be called continuous-current transmission, alternating-current transmission and polyphase-current transmission. They have been developed in the order named. All our street-railway systems are using the continuous current for driving their motors, and the pressure used is about 500 volts. A higher pressure would be more economical as far as saving power is concerned, but would be more dangerous to life and to machinery; hence 500 volts

is about the limit of the pressure used in commercial work where continuous currents are employed. There are some exceptions to this.

Alternating-current transmission is yet in its infancy. While it has the advantage of allowing high pressure in the primary transmitting wires, which can be transformed to safe pressure in buildings and at points of consumption, yet, for power transmission, it is not considered the best, on account of the necessity of the motor being or running at all times in synchronism. Sudden changes in load or overload may affect its speed and cause trouble. It is also troublesome to start a synchronous motor. Alternating currents are often used to good advantage in power work by being made continuous with a rotary transformer. These currents are used to best advantage in lighting.

Polyphase currents, in reality, are compound alternating current. They offer great advantage in power trans-

mission. By their use the electrician can use a motor of high efficiency, that does not need to run in synchronism.

No sliding or revolving contacts are required. The current required in the armature is an induced current, and has no metallic connection with the external currents. On this account such motors are called "induction motors." Polyphase currents admit of a circuitous change of polarity in the field magnets of the driven motor, making it possible for it to start itself with a small load. These currents have the advantage of transformation. Polyphase currents, induction motors and rotary transformers, without doubt, are the best avenues through which we can bring our water powers to manufacturing and trade centers.

Since electrical power is better adapted to speed and haulage than steam, we can expect in the future to see our great railroad lines operated

by the now valueless water powers in the country.

The agent that makes it possible to use the energy of the distant water falls is that quiet looking engine we call the dynamo. Without it, electricity could be of little value to humanity. By its mysterious powers we are enabled to harness the mountain torrent and distribute its energy in our dwellings and factories. The sunlight absorbed to carry the water to the hills and peaks is returned to us as an article of commerce.

When the dynamo is dissected it proves to be nothing more than a pump that can put in motion that unseen something we call the electric fluid, and any loss of energy through it is due to friction; that is, electrical friction, as the mechanical friction is a very small ratio of the power applied to it. This will be evident when we state that it is not uncommon for a dynamo to convert into electrical energy 95 per cent

of the mechanical energy applied to it.

The further energy that is lost in transmission is due to the friction of the current passing through the transmitting wires, hence is lost in heat. The electrical engineer reduces the total loss by putting his transmitting current under high tension or pressure, thereby reducing the quantity of current that must flow. The polyphase system of transmission enables us to convert electrical energy into higher or lower tensions to suit our particular needs, and for its discovery and outline we are indebted to that fearless and intellectual son of Servia, Nikola Tesla.

CHAPTER XVIII.

SUGGESTIONS.

There is no form of energy that is so far-reaching in its benefits to the welfare and comfort of the world as electrical energy.

There is no force or means so plentiful in a static condition as electricity.

There is no kind of power that can be so absolutely controlled by a consumer as electrical power.

There is no source of energy so easy of access or so richly provided as water power.

There is no form of motion that is more perpetual than a water fall.

There is no machine that depreciates so little for the amount of work it performs as the dynamo.

There is no medium of trans-

mission so little wasted by transmitting power as a wire.

There is no form of investment more certain of continual returns than an intelligent development of electrical water-power plants.

There is no reason for delaying the use of our water falls, except that our investors do not as yet fully appreciate their importance.

We have attempted to tell a few of the facts concerning electricity and water power, and have endeavored to put them in a form that will allow of their being grasped by those who can not spend the time necessary to study these subjects in a technical way. We have entered very little into detail, and only on points that we deemed necessary.

The harnessing together of electricity and water power is of special interest to many. The proposition is so far-reaching that it excites the curiosity and admiration of all.

There are water falls enough to

turn all the machinery required for the comforts of mankind for centuries to come, and, unlike other sources of energy, they are exhaustless.

By the union of electricity and water power our great and now smoky manufacturing cities can be made models of comfort and cleanliness.

By the combination of these two forces, the locomotive with its soot and cinder can be hushed and side-tracked.

By the adoption of these sources of energy and heat our great blast furnaces and smelting works may become odorless and clean.

By the linking together of these two most bountiful gifts of Nature, the labors of all the world may be lightened and the comforts of all its inhabitants increased.

The recent rapid development in useful applications of electrical science has opened up a wide field of possibilities, and, what a few years ago would have been thought utterly

visionary, men now are ready to look upon as only a question of time, sure to be attained in the end.

CHAPTER XIX.

REPRESENTATIVE ELECTRICAL-WATER-POWER PLANTS.

When the foregoing papers were being prepared it had not occurred to the writer to add the following somewhat general descriptions of the representative electric-water-power plants of the United States. This idea was suggested by the publishers of the ELECTRICAL REVIEW, and it has been indorsed by so many friends of water-power development that the writer has decided to add such synopses of the noteworthy propositions as he can obtain in the limited time before final publication.

For these general facts concerning the following advancements in this new science the writer is indebted to the leading spirits in the various enterprises—men who have grappled the new problems with a spirit of

achievement, such as has been manifested only in this electrical age.

THE FRESNO ELECTRIC-WATER-POWER PLANT.

The latest and most unique power plant that has come to public notice is that of the San Joaquin Electric Company, at Fresno, California. Fresno is a city of the plains, being the center of a rich fruit-growing section of the Golden State. Its fertility depends greatly on the water carried from the Sierra Nevadas by the irrigating ditches. The town, being distant from wood or coal supplies, offers a favorable field for the cheap power and light that can be had from the mountain streams, 40 miles distant.

The San Joaquin company was organized early in 1895. They had completed in June, 1896, one of the most daring feats in the transmission of energy that has been recorded. Away up in the head waters of the

San Joaquin River, at a point about 60 miles south of the Yosemite Valley, two mountain torrents meet and form the north fork of the river. By a shrewd application of engineering, both of these streams are tapped by wooden flumes in such a manner that the supply of water can be had from either or both of them. The flumes empty into a ditch which takes a southerly direction at an easy grade for seven miles, where it empties into a reservoir on the top of a mountain spur, some 1,400 feet above the river level. From this reservoir a steel pipe 20 inches in diameter leads directly over the brow of the mountain, almost perpendicularly into the gorge below. The pipe at the top is about one-eighth of an inch thick, and increases in thickness as it descends to the receiver, which is made of three-quarter-inch boiler steel, and is firmly anchored to the granite foundations of the power house.

The power house is built on a solid

granite bluff about 40 feet above low-water mark in the river, and is constructed of cut granite. It contains space for four 500-horse-power water wheels of the impact type, and two exciter wheels of about 20 horse-power each. Each of the above wheels drives a direct-connected multipolar generator. The four large generators are of the Tesla polyphase type, and generate at a pressure of 700 volts, with a capacity of 340 kilowatts each. Step-up transformers raise the pressure to 11,000 volts, and the energy of the mountain stream is carried 34.4 miles over the well constructed pole line to Fresno, on the plains below. By the use of step-down transformers at Fresno, the current is converted to pressures necessary for the different uses to which it is applied, the pressures ranging from 115 volts to 3,000 volts.

This daring feat in hydraulics brought to light some features that are of more than ordinary interest.

The gauge shows a static pressure of about 610 pounds per square inch at the lower level of the pipe line. A sudden stopping in the water flow, on one occasion, raised the hand on the pressure gauge to the astounding height of 1,000 pounds per square inch, and the pressure returned to nearly a like distance below 610, and kept up a reverberating for over 30 seconds. The great pipe writhed like a huge serpent, and the commotion in the interior sounded like the firing of distant cannon. The great strength and elasticity of the steel are the only safeguards in such sudden changes of flow. The water is applied to the Pelton wheels by the use of deflecting nozzles. A stream of water from one of these will bore a hole through a three-inch plank in a few minutes; it will tear a hole through a three-eighths-inch piece of steel in a few days; concrete melts before it like sugar. The only successful mode, up to the present, of safely stopping

the motion of the water from the nozzle is to put a heavy cast-iron plate in the tail-race in such a manner that it can be quickly replaced when worn out.

The general plans admit of the power house being duplicated when Fresno and vicinity require additional power.

This unique plant is a success in all its details, and is a forerunner of hundreds that will be made on similar lines. It can at present deliver into Fresno nearly 2,000 horse-power of energy.

THE NIAGARA FALLS HYDRAULIC POWER AND MANUFACTURING COMPANY.

The great work at Niagara Falls that is being prosecuted by the Niagara Falls Power Company has attracted so much attention during the past five years, that many people think Niagara was harnessed for the

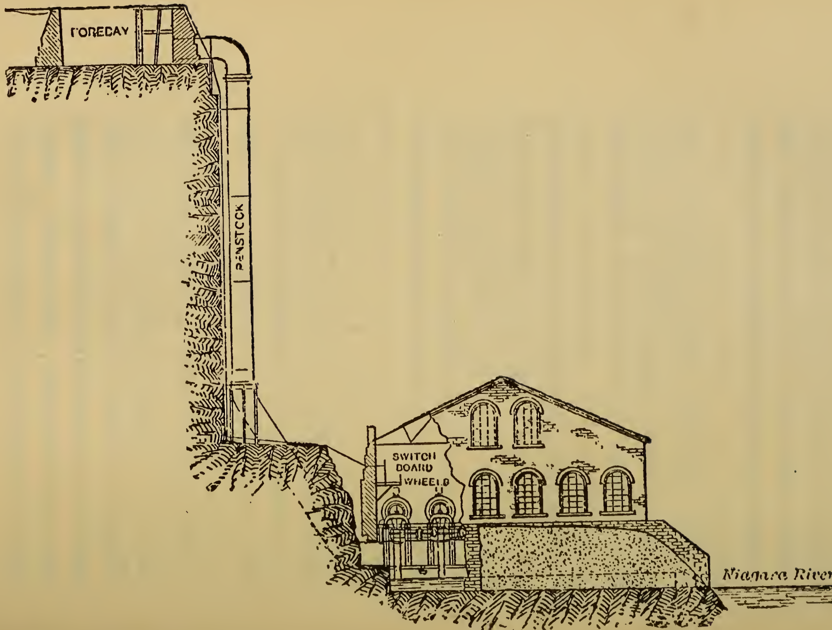


FIG. 5.—CROSS-SECTION OF THE NIAGARA FALLS HYDRAULIC POWER AND MANUFACTURING COMPANY'S NEW 6,000 H.-P. POWER HOUSE. WHEELS OPERATED UNDER 210 FEET HEAD.

first time when their great wheels began to turn.

The above great proposition will be treated later in these papers, but the present paper will be devoted to a great power that has developed so quietly that it has almost escaped public notice.

As early as 1725, Niagara power was used by the French for sawing logs. From 1800 to 1825 some four or five mills were operated at various points along the river. About the year 1850, a plan was laid to make a canal from a point about one mile above the Falls on the American side, to the high bank of the river below the Falls; and from the latter place it was intended to run the water through wheels into the chasm below. After the many reverses and discouragements, always met with by the promoters of so wild a scheme, the canal was finally finished in the year 1861.

The War of the Rebellion evidently

had much to do in cooling the ardor of its leading spirits, as we find no further progress until 1870, when the first grist mill was built and operated from the canal. In 1877, the Niagara Falls Hydraulic Power and Manufacturing Company was formed, into whose hands the canal and all its belongings fell, and since that date there has been a steady increase in mills of all kinds. The canal to-day is furnishing over 10,000 horse-power of energy, and when improved to its full extent can furnish over 100,000 horse-power.

The most interesting part of this great power is the study it has afforded to the student in hydraulics. We first find the "current wheel," followed by the "undershot" and "flutter wheel;" next the early and crude forms of "turbines." Later the turbine was used under heads of 50 to 60 feet, and this was thought to be the extreme height of head to which a turbine could be subjected.

Each new proposition dipped deeper and deeper into the rocky chasm with its tail-race, until 1895, when the daring engineer now in charge, decided to use the full fall of 210 feet. There is now nearly completed a power plant worthy of more than ordinary notice. When finished it can furnish from its generators about 40,000 horse power of electrical energy. A special type of horizontal turbine is used, and each wheel is connected to two generators, one at either side of wheel, and attached to same shaft. Each wheel with its two generators furnishes about 2,000 electrical horse power, and comprises a unit of the plant's power. There will be 20 of such units when the power house is complete.

The above company has experienced a gradual development in the line of transmitting power electrically. We find first some old dynamos in a mill cellar, later a loft was built for a city lighting plant, next, a

power generator was installed and electric power sold to various manufacturers. Following this was a new plant in which was installed the latest and best lighting machinery. Now comes the mammoth plant just mentioned, in which the full height of the fall is utilized. The wheels and dynamos are placed at the lower river level, and the energy will be carried on wires to the city above and distributed to the many users of this cheap and reliable power.

The Pittsburgh Reduction Company have built a large aluminum smelting plant on the bank above the power house, and will use a great quantity of the new power in supplying civilization with this new and valuable metal.

The growth of this remarkable water power has been gradual but sure. Some of the traces are still to be seen of the steps taken by this energetic company as they felt their way up to the present modern and

magnificent power plant, but the Niagara Falls Power Company's plant, which is the result of all past experience, was brought before the public so suddenly and so forcibly that many failed to learn what the silent workers were doing.

THE FOLSOM, CAL., POWER AND TRANSMISSION.

Of the recent demonstrations of long-distance transmission, none stand out more boldly, or have attracted such world-wide attention, as the development at Folsom, Cal., by the Folsom Water Power Company and the Sacramento Electric Power and Light Company.

There are various reasons for this interest. The first and greatest, perhaps, is that it was the first attempt to transmit great quantities of power electrically to so great a distance in the western hemisphere; second, the work from beginning to end is American. While the Niagara Falls Power Company were investigat-

ing the work of European engineers and incorporating their ideas into the great plans adopted, the Folsom plant was steadily and surely being crowded to completion by native Americans. Another cause of interest is its locality. The great coal fields that help to enrich the eastern and middle sections of our country are wanting on the Pacific coast, but the mental energy that causes nature to contribute to the welfare and happiness of mankind is not wanting. The spirit of turning promptly into account the lessons so recently taught us by science, is so marked in this great transmission, that its success stands out a new and blazing star in the glory that crowns the already famous Golden State.

A most singular coincidence, too, is that this great power plant is located only a few miles from the spot that produced the first gold in California. The whole world was electrified by the developments in the

American River valley in "49." In "94" a great work was nearing completion that was soon to electrify the scientific world with positive demonstration that 4,000 horse-power can be carried 22 miles as a profitable investment to the promoters of such a project, as well as to the patrons of the power and light furnished.

The power house is situated at Folsom City, 22 miles North and East of Sacramento, the capital of the State. The American River is a tributary of the Sacramento River, and its many sources are high in the Sierra Nevada Mountains. Folsom is situated at a point where the river finds the level lowlands, and is the remains of a once flourishing mining town. Its great areas of washed surface, and its tumbled-down appearance, are the only indices to its former greatness. The surface of the lowlands is composed of a tough red and gravelly till, but the foundation rock is a good quality of gray granite.

About two miles up the rocky gorge from Folsom, at the head of a series of rapids, the great plant gets water from the river. At this point is constructed one of the finest granite dams in America. The head-works are constructed of cut granite and are equipped with hydraulically moved gates. From here a great canal is cut through the granite bluffs nearly 2,000 feet to the State prison power house. At this point about 800 horse-power is used for manufacturing, and in the various operations pertaining to the quarrying and handling of the fine cut granite produced by the State in its prison works.

This canal is extended to Folsom City, one and one-half miles below the prison, to a high bluff situated between the town and river. On this bluff is constructed a double forebay, and each basin is tapped by two of the great penstocks that carry water to the four pairs of horizontal turbines below. Each penstock is pro-

vided with a hydraulically moved gate.

The power house is two stories high and is substantially built of brick. It contains four units of power, duplicates of each other. Each unit consists of a pair of specially built horizontal turbines that furnish 1,260 horse-power under 55 feet head. The turbine shaft is connected directly to a 1,000 horse-power three-phase generator, that furnishes to the step-up transformers a current of 800-volts pressure. The turbines make 300 revolutions per minute, and have connected at the opposite end from the dynamos a 15,000-pound flywheel, to aid in their government.

There are, besides the four 750-kilowatt generators, two 500-volt exciters. These are driven by two smaller turbines. The six dynamos occupy the first story of the power house, where is also found the switchboard. The turbines are in a wheel house beside the dynamo

room, and their great shafts extend through the brick walls.

The second story of the power house contains the 12 step-up transformers that receive the 800-volt current and transform it to a current of 11,000 volts, ready for transmission. There are also two rotary blowers to keep the transformers cool when heavily loaded.

Two well-constructed pole lines carry this high-tension current to the sub-station in Sacramento, 22 miles distant, where it is again transformed by the step-down process to the various pressures convenient for the work to be done.

The sub-station is a very substantial and neat brick building located on the corner of Sixth and H streets. It contains three large synchronous motors that receive current at 500-volts pressure from the transformers in the second story. These motors drive the street railway generators that furnish power for all the street

cars in the city. They also drive the great arc dynamos that furnish light for the streets. The three mentioned motors can all be connected to one drive shaft, from which all the dynamos can be driven.

The incandescent lighting current leaves the transformers at a pressure of 125 volts, on a four-wire system, to all parts of the city. Three wires are for the three-phase current, and the fourth is a neutral wire.

Power can go directly from the transformers to synchronous and induction motors, or it can be furnished from the street railway generators. The sub-station contains the offices of the company, and with the exception of the wires overhead, it has the appearance of a neatly designed business block. (A vast improvement over ordinary electric stations.)

This great plant started up on July 14, 1895, and has been running night and day ever since. It has demonstrated that great quantities of power

can be carried great distances ; it has demonstrated that communities lacking natural fuel may still be rich in power, and it has demonstrated that Americans can build great electrical power plants, and adapt themselves to the conditions that nature provides.

The water supply at Folsom is sufficient for several more such power stations when they are demanded.

POWER AT THE FALLS OF THE WILLAMETTE, OREGON CITY, OREGON.

The Willamette River drains the most populous valley in Oregon. The valley extends in a northerly direction, and is found in the western part of the State, bounded by the Cascade Mountains on the East, and by the Coast Range on the West. The river is a combination of the streams from these mountains, and winds its way north to the Columbia River in the vicinity of Portland.

The vicinity of Oregon City seems destined to become noteworthy. Some-

time during the long ago, when old Mt. Hood was in the vigor of his youth, an attempt was evidently made on his part to possess the lower valley by throwing great fields of lava across it at the above mentioned point. Although the lava beds lay directly across the valley several hundred feet in depth, the river has cut through them gradually until it now falls over a broken precipice, about 40 feet high, to the lower level. The waterfall, as well as other favorable conditions, made this a home for the Indian. Even now there can be found a few remnants of the tribe that possessed these Falls before the appearance of the white man. Some of these aged and tottering redmen tell how this valley was owned by the coyotes previous to the possession by the Indian. They tell how the great coyote chief would marshal his forces on the high bluffs, and then march down to give battle to the salmon and eels during their attempts at scaling

(8)

the falls to take possession of the valley above.

Mt. Hood, coyote and Indian have each in turn relinquished his right to these beautiful falls, and they now are the property of the Portland General Electric Company, of Portland, Oregon.

A canal has been built to allow the steamboats to pass up the river to the many small cities above. A portion of this power is used for paper mills, woolen mills and various other kinds of manufacturing establishments. A great quantity has also been carried to Portland, some 14 miles away, for lighting and power purposes.

The Portland General Electric Company have control of both sides of the river at the Falls of the Willamette, and on the east side is found their Station A. This station is constructed on the lines of a manufacturing plant; that is, they use small units of power, and these are harnessed up by the use of line shafts, belts, etc. Station A

was a marvelous station when it was first constructed. It has a capacity of 3,000 horse-power, and now contains eight 1,500-light alternating-current generators, one 2,000-light alternating-current generator and nine 100-light arc dynamos.

These dynamos have been furnishing light in Portland for some years past,and the success that attended the efforts of the promoters at this station, as well as their experience in its manipulation, led to a conception of an ideal power station.

This power station is being gradually built as demands are made for power and light by the cities and towns within reach. Already five of its great dynamos are pouring into Portland the energy to propel all of the electric and cable cars in the city. The many suburban lines also get their power from this new power house, known as Station B.

This great power house and its equipment furnish many new and

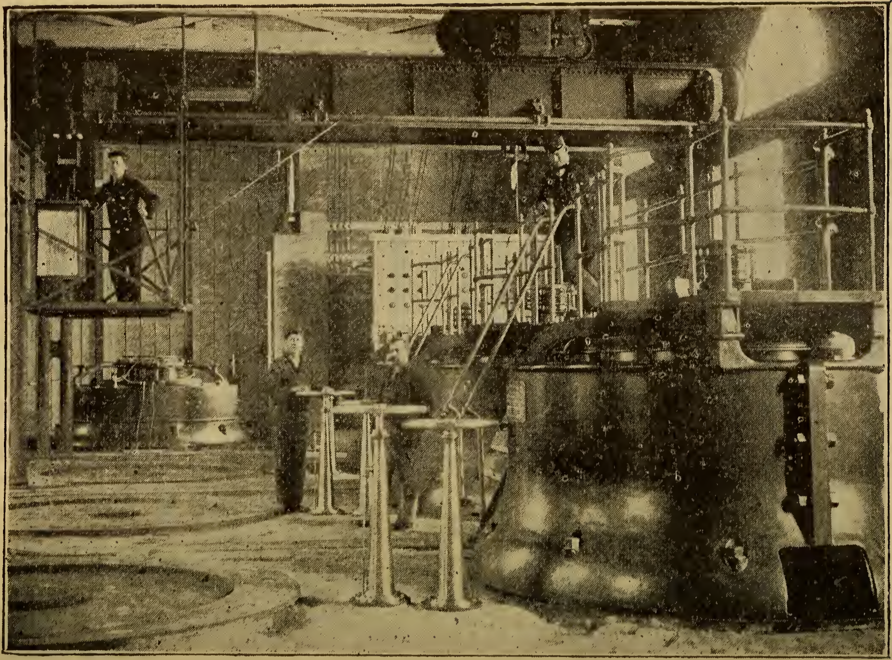


Fig. 6.—Interior View of "Station B," Portland, Ore., General Electric Company's Transmission Plant.

valuable lessons to the student in mechanics. While it looks in general as a simple proposition in mechanics and hydraulics, yet its advancement and final success depended upon the solution of some of the most intricate problems that have yet appeared in developing electrical - water - power plants. It being an unqualified success makes it a lasting memorial to the energy of its promoters, and the genius and untiring zeal of the engineer who designed it and forced it to completion.

Some of the problems solved deserve special consideration, and a few of them will be noted. The most important one is the great variation in the head. There are times in the year when there is an available head of 42 feet. This usually occurs in the late Summer and Autumn, after the Columbia River has fallen. During the Summer months, when the Columbia River is high, from the melting snow in the mountains, it backs the

Willamette up often to the height of 20 feet, thereby deducting that amount from the height of the Falls. Since it is impractical to make a water-wheel run successfully at a given speed under variable heads, it was necessary to design a plant that could furnish its full power under a 22-foot head, a 42-foot head, or any head that would range between these two extremes.

On account of these changes in the tail water, the use of horizontal wheels was practically out of the question. If they could have been used, the problem would have been less grave, as a high head wheel and a low head wheel could have been attached to a horizontal dynamo, one at either end, and, by the use of friction clutches, these wheels could be connected or cut out at will.

The design adopted and in use for each unit of power is two vertical turbines, whose upright shafts can be connected at will by tightening a great

connecting belt. The smaller turbine is on the side of the power house next to the river, and is designed to furnish 600 horse-power from 32 feet to the maximum head. The shaft of this turbine extends up to the dynamo-room floor, where it forms the axis of the armature of a great dynamo, which is the electrical unit of each section.

The large turbine is on the canal side of the power house and is designed to furnish 600 horse-power at the lowest head of water. The two turbines are in the same iron penstock, and discharge into one large draft tube. The smaller wheel can be disconnected, when the head is too low, by taking the pins out of a coupling below the drive pulley. It is now plain that the small wheel can furnish the desired amount of power alone under the higher heads; also the large wheel can furnish it alone under the lower heads; and the two wheels connected can furnish it under the

mean heads. The wheels and dynamos are of American design, and are regulated by governors, which are also of American design.

A second difficulty was to support the great weights that were found in the shafts and pulleys. These in the main are supported by a system of collar or ring bearings that run constantly in oil. The weight of the armature is sustained by means of a drum piston head attached to the small turbine shaft. This fits closely into a cylinder that is supplied with oil at a pressure of 175 pounds per square inch. The oil is furnished from a separately driven pump, and the small wheel that drives it is automatically governed by the motion of the accumulator ram. All the thrust bearings are inclosed by water jackets, through which a constant flow is kept up by a separately driven water-pump, and by a gravity system from flumes.

When this station is finished it will

constitute 22 sections, each one containing two water-wheels. The first section contains the two small pumping wheels, the second, third and fourth contains each a large and a small turbine, as described above; and the fifth contains two 500 horse-power turbines that drive the duplicate exciter dynamos. Seven more sections are in the course of construction, and the balance will be built as necessity demands.

The foundations and the building are made from the finest quality of concrete, and rest on bed-rock from 25 to 36 feet below low-water mark.

A third problem was transmission. The sub-station is in the center of Portland, 14 miles away. Willamette power must be carried to this distributing point with as little loss as possible. The plan adopted is high-tension three-phase current, and the dynamos are constructed to generate at a pressure of 6,000 volts, which is

transformed to lower voltages in the Portland station.

These machines are most extraordinary in their construction and performance. As stated before, they are of the vertical type, and were designed for this plant. The field magnets are supported by a great iron cylinder, about nine feet in diameter and five feet high. It is shaped so as to give a massive, yet symmetrical appearance. This great base is surmounted with a walk that surrounds the collector rings, and the walk is inclosed by a substantial and neatly designed railing, the whole presenting an artistic appearance, combining the desirable points, compactness, simplicity, capacity and durability.

Each of these dynamos was designed to generate 600 horse-power at 200 revolutions. Practice has shown that they have generated 900 horse-power for days at a time, and it is thought that they could furnish 1,200 horse-power for a few hours with safety.

They each have a weight of about 57,000 pounds.

The two exciter dynamos are of a similar design, but they are only about three and one-half feet high. They furnish a direct current of 550 volts, and each has capacity to excite all of the large dynamos when the station is completed. The necessary switchboards are placed in convenient places, and from these the wires lead direct to the sub-station in Portland.

The sub-station is a neat, businesslike institution. The lower story contains all of the transformers, switchboards and workshop. One apartment contains all of the stationary transformers; a second room contains all of the measuring instruments, switchboards and rotary transformers, and a third room is used for a repair shop.

At present there are but two rotary transformers used. Each of these takes the current from one of the large dynamos, after it has been

stepped down, and makes of it a direct current of 550 volts pressure for the street-car and motor lines. The current for lighting purposes leaves the transformers direct to the city mains.

The second story of the sub-station contains the offices of the company. They are commodious, neat and finely furnished.

Here is a truly representative power plant. It is cosmopolitan in all its bearings. When finished it will have in use more water-wheels than any other known electric-power plant. It will operate more large dynamos than any known plant. It will have a capacity of 12,000 horse-power at the power station, in Oregon City, and the loss in transmission to Portland is within 15 per cent.

ELECTRIC POWER IN CANADA'S CAPITAL, OTTAWA, ONT.

In reviewing the water-power-electrical development, it will be noticed

that none were quicker to see its advantages, or were earlier in the field, than our nearest American neighbors. It can be safely said that the first large, substantial electric-water-power building in America was built at Ottawa, Ont., by the Standard Electric Company. It is a massive stone building, equipped with all the best machinery known up to the date of its completion in 1891. This is referred to as Station No. 1 in the description of stations that follows.

Canada has many noteworthy developments, but no city contains so many of them as her capital on the Ottawa River. This river is a tributary to the St. Lawrence and drains a heavily timbered valley in southern Canada. It also furnishes an outlet for a number of lakes in the provinces of Quebec and Ontario. The river contains an abundance of water at all times during the year, and enters Ottawa with a grand leap known as the Chaudière

Falls. The well timbered country up river and the above named falls make Ottawa one of the greatest lumbering and water-power cities in America, and this is beyond doubt why her citizens were among the first to use electricity generated from their natural power supply.

All of the lighting and power, except that used by the street railways, is furnished by the Ottawa Electric Company. This company is an amalgamation of three electric lighting companies, and has four separate water-power stations, also a station operated by steam as an auxiliary, used only during the Winter months, when the river is filled with anchor ice to such an extent as to interfere with any of the water stations.

Station No. 1 (mentioned above) contains a number of large alternating lighting generators, also several large power generators, all of Canadian design and make. These are

driven by means of counter-shafts and belts from five 66-inch water-wheels, running under 16½ feet head. The wheels are all of Canadian manufacture, and use governors from the United States. The capacity of the five wheels is 1,825 horse-power, and they are all of the vertical type, in which bevel core gears are used to transmit the power to horizontal shafts.

Station No. 2 is the arc lighting station, and contains three vertical turbines 60 inches in diameter, and one 48 inches in diameter. The power is transmitted to counter-shafts in this station by the means of rope drives, and the estimated capacity approximates 1,468 horse-power.

Station No. 3 is the steam auxiliary, and has a capacity of 1,200 horse-power.

Station No. 4 contains two 60-inch and one 48-inch vertical water-wheels, running under 16½ feet head. This station is devoted to alternating light-

ing, and uses governors from the United States. The wheels of this station, as well as Station No. 2, are of Canadian make and design. The capacity of Station No. 4 is 920 horse-power.

Station No. 5 contains four 48-inch and two 60-inch vertical water-wheels, running under about 14 feet head. This station furnishes direct current for incandescent lighting, and uses governors from the United States. The capacity of this station is 1,188 horse-power.

This shows an aggregate of 5,401 horse-power, exclusive of the steam plant, furnished by one company for the lighting and the small power of the city.

Added to the above is the power from the Ottawa Electric Railway Company's power plant. This plant is run by water also, and has a capacity of 1,500 horse-power, making a total of 6,901 horse-power used in only one of Canada's many cities.

The above mentioned railway company are among the first that attempted to use water power to drive electric generators for street railway purposes. They have increased their power and improved their machinery until the plant has a capacity of 1,500 horse-power in three units; one 700 horse-power generator, and two 400 horse-power generators. These machines were designed and built in the United States.

The water-wheel gates are operated in this station by hand through a frictional gearing, and the extreme fluctuations in voltage are overcome by separately exciting the field magnets of the generators.

This plan seems to have been original in this plant, as it also was in several plants in the United States, and the success that has attended its use in all cases should commend it to the serious consideration of the owners of water-power plants in America.

The idea is to excite the fields from a constant-speed dynamo, thereby keeping a given pressure; hence, even current for exciting purposes. The voltage on the power generator can then only vary in the same ratio as the speed, where, if self excited, it would vary in about double the ratio of the speed.

Ottawa has 30 miles of electric railways. It has some fine parks and athletic grounds that furnish patronage for the street railways. It is a city of 50,000 people, and boasts of having an incandescent light for each of its population. The city is three and one-third hours by rail from Montreal, the metropolis, and is only a few hours from the United States line.

Ottawa is recognized as being of first importance, electrically, in the Dominion, and enjoys the distinction of having first solved the snow problem, demonstrating that an uninterrupted electric street railway service

could be successfully maintained throughout a Canadian Winter.

There are many more interesting water-power plants in Canada, but the writer has not the time or space to devote to them. The data for this paper was furnished by the general superintendent of the Ottawa Electric Company, to whom obligation is acknowledged for the courtesy so promptly shown.

CHAPTER XX.

THE GREATEST OF ELECTRIC-WATER-POWER PROPOSITIONS, NIAGARA FALLS.

So much has been published about this great power proposition, and it has come from such eminent authority, that it seems almost unpardonable for the writer to make any attempt to add to a subject that has been so thoroughly discussed. In fact, nothing can be added. The newspapers, magazines, technical journals and encyclopedias have all furnished such accurate and reliable information that it is out of the question to produce anything that has not been written many times before; yet if this great installation were omitted from these papers, they would be less complete than now, so at least an effort

must be made, even though it falls far short of additional information.

The harnessing of Niagara on so large a scale as proposed by the Niagara Falls Power Company is a crowning achievement, and marks an epoch in history. A few thousand years hence, when gravity can be reversed at will, when all needed power can be had direct from the sun's rays, when food can be made directly from the elements, when now unknown forces are subservient to man, and when the great power house is crumbling to dust, then may be found the papers that are sealed in its corner-stone. They will be relics of the "Electric Age," and the student in history can learn that at about the beginning of the twentieth century the Niagara River represented about 8,000,000 gross horse-power at the point where the falls were at that time; that a great corporation was formed to develop about 450,000 horse-power; that a commission of

great engineers sat in London (then the greatest city of the times); that this commission examined plans from all parts of the world, and adopted the idea of transmitting energy by the primitive electricity to parts of the land where the primitive factories of that age were located. The historical student may even smile at the method of lighting used at that time, when only five per cent of the energy used was converted into light.

Coming back to the present, we can say that some of the wheels of this great power plant have been running constantly for a year and meet the expectations of their designers. The Niagara Falls Power Company have reason to believe that their great plans were well founded, and are now at work excavating for space to install more water-wheels. The following is the work completed up to the present:

First, is a great tunnel. This is an excavation that meets the lower river

level almost under the new Suspension Bridge, near Prospect Park. This tunnel is a brick arch starting at the river level, and extends up along the river a distance of 7,000 feet. It runs immediately under the business part of the city, and its purpose is to serve as a tail-race for the great turbine wheels at its upper end. The extreme up-river end of the tunnel is 145 feet below the upper river level, and this difference is the head used in furnishing water pressure for power development.

Second, a canal 200 feet wide by 12 feet deep is cut from the river to the power house, and great pen-stocks carry the water down the pit to the large double water-wheels. These are the most powerful wheels ever built. They were designed by engineers in Switzerland, and can develop 5,000 horse-power each. They consist of two vertical wheels about five feet in diameter. One is placed 15 feet above the other, and the water enters the

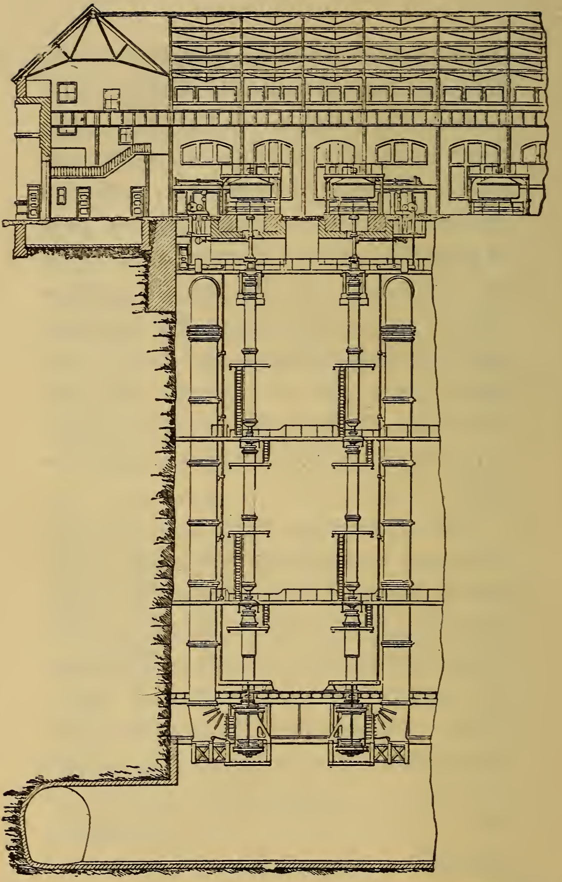


FIG. 7.—PARTIAL VERTICAL SECTIONAL VIEW OF THE NIAGARA FALLS POWER COMPANY'S GREAT PLANT.

wheel case between the two. The disk of the upper wheel furnishes the only cover for the wheel case, hence the pressure against it supports the wheel shaft, as well as the weight of the dynamo parts above.

The wheel shaft extends up to the surface and is surmounted with the inverted cup-shaped dynamo field support. The wheel shaft mentioned is a hollow steel cylinder 38 inches in diameter, except at the bearings, where it is reduced to a solid shaft 11 inches in diameter. The wheel cases are made of iron that is three inches in thickness, and are well calculated to withstand the fluctuations in pressure caused by governing the turbines. The speed of the wheels is 250 revolutions per minute at normal, and the regulating is done by governors designed by the engineers that planned all of the hydraulic machinery used.

It is understood that each unit of power consists of the pair of turbines on the lower end of the shaft, just

referred to, and a great dynamo at the upper end. This dynamo is a type of the Tesla polyphase alternating-current system and generates a two-phase current at a pressure of

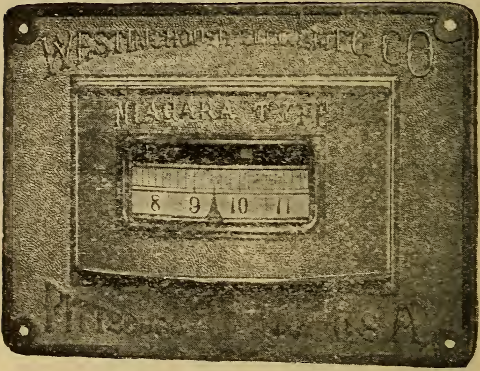


FIG. 8.—SPECIAL TYPE OF ALTERNATING CURRENT AMMETER USED BY THE NIAGARA FALLS POWER COMPANY.

from 2,000 to 2,400 volts, according to the distance that the power is transmitted.

These greatest of electrical machines are practically a summing up, on a

comprehensive scale, of all the known advantages in dynamo construction and power transmission, and were designed by the engineers of the Cataract Construction Company, who had in charge this part of the work. They have a capacity of 5,000 electrical horse-power, a weight of 170,-000 pounds each, and are by far the most powerful dynamos ever constructed.

The armatures of these dynamos are of the vertical type; that is, they set on end and they are stationary. This allows the current to leave them through solid connections, which is of great advantage where such a volume of power passes. No commutators or collectors are required. The wheel shaft extends up through the standing armature and connects the umbrella or cup-shaped field-magnet ring. This field-magnet ring or cylinder is made of nickel-steel of the highest magnetic qualities. The fields themselves are attached to this

ring and revolve around the motionless armature. The only sliding contacts are the collector rings that receive the exciting current for the field magnets. The power for exciting purposes comes from the great dynamos, after being straightened out by a rotary transformer.

The static transformers of this installation are all found in a substantial building across the head canal from the power house. The switchboards are ideally located on an elevated platform near the center of the building.

Only one power house has been built up to the present, and it is not yet finished. When completed, it will have 10 sections, and each section embraces one of the water-wheels and dynamos just mentioned. The building is made from cut stone, lined inside with tile brick, and is completed for four sections. Three of these are equipped with working machinery that can furnish 15,000 horse-power

of the 50,000 that will be furnished from this one great installation.

It will be understood that each and every piece of machinery in this plant was especially built for it, even the voltmeters and ammeters. The great traveling electric crane that moves from end to end of the power house had to be designed for the immense weights that must be sustained in handling the parts during construction.

All of the machinery in this installation was built in America. Some of it was designed in Europe, but all designs were selected on a competitive basis, and some handsome cash premiums were paid to Americans in recognition of the worth of designs presented. While the great scheme is in America, its interests are not all here. They are of a more cosmopolitan character. The original plans call for one more tunnel on the United States side of the falls, and two more on the Canadian side.

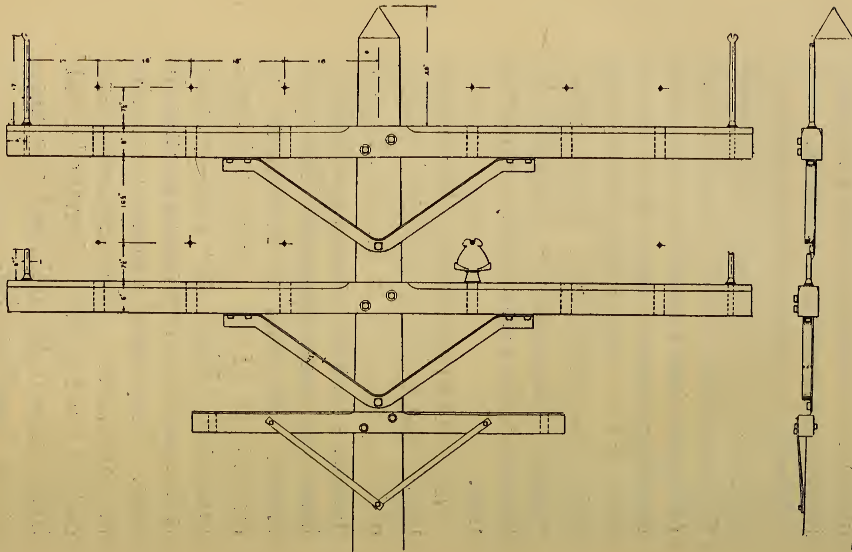


FIG. 9.—TOP OF POLE AND FIXTURES USED ON THE ELECTRIC TRANSMISSION LINE WHICH WILL SUPPLY NIAGARA FALLS CURRENT TO BUFFALO, N. Y.

This proposition is not the venture of an individual or of a people; it is a creation by peoples, a product of the times.

The Niagara Falls Power Company is preparing to furnish power as a business proposition. It can furnish it in large or small quantities, at home or abroad. By the use of the polyphase system it can furnish power in quantities at any desired point in the eastern part of the United States or Canada. Within a radius of 100 miles it can furnish power cheaper than steam. And there are propositions where power is used that could economize by using Niagara energy at a distance of 200 to 400 miles away. The long-distance transmission problem is fully solved. It is now a problem of installation and confidence.

The company owns large tracts of land in Niagara Falls and vicinity, and can furnish power for any or all kinds of manufacturing purposes, as

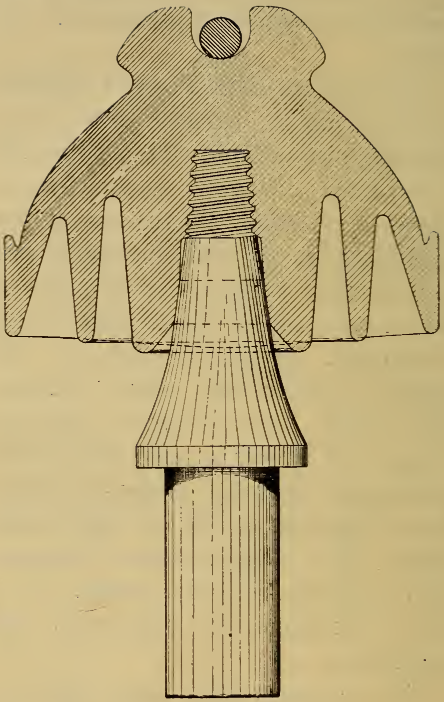


Fig. 10.—Special Type of Porcelain Insulator Used on Niagara Falls-Buffalo Transmission Line.

well as a site for works, in that centrally located section.

Up to the present time the power supplied from this plant aggregates 4,500 horse-power. This is supplied to tenants of the company and other customers within a radius of about a mile. A line for transmitting 20,000 horse-power to Buffalo is now in process of construction.

The purposes for which this power is now used are: The manufacture of aluminum by the Hall electrolytic process, the manufacture of carborundum under the Acheson patents, the production of calcic carbide and the operation of the polyphase motors. Two motors of 300 horse-power each furnish the supply of power in an electric lighting station, also current for several street railways, including the one between Niagara Falls and Tonawanda. A number of additional plants are in process of installation by tenants of the company, and the aggregate power contracted for

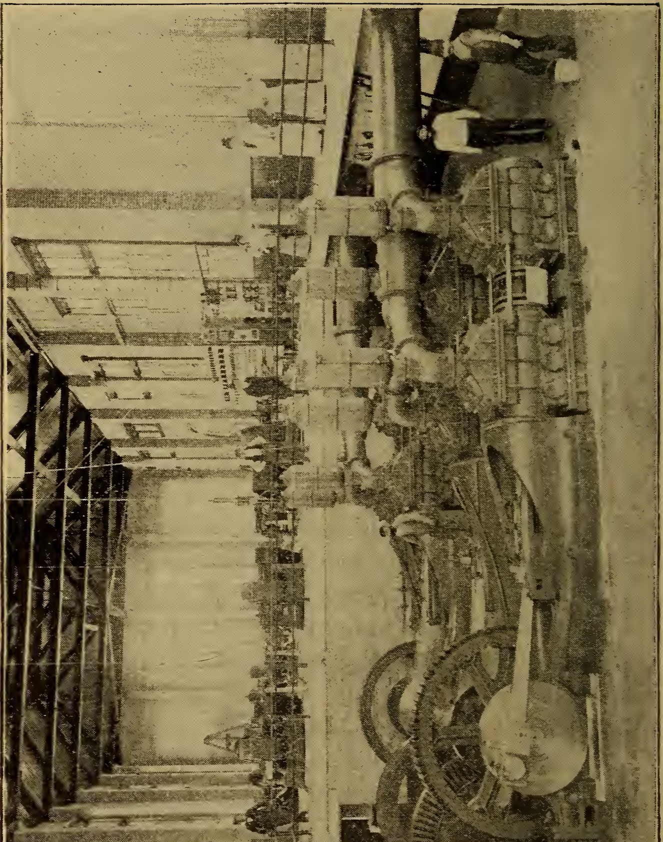
amounts to about 10,000 horse-power. The water flow at Niagara is ceaseless, hence its power is reliable. In time it should propel every railway train between New York and Chicago, as well as furnish power for many of our manufacturing centers.

Already on a special occasion it has turned wheels in New York city, nearly 500 miles distant.

CHAPTER XXI.

FURTHER PROOFS THAT HARNESSING WATERFALLS ELECTRICALLY IS A REALISM.

Among the more important developments in the United States there stands one of peculiar interest; namely, the Austin power and transmission. This is a widely known work established at Austin, Texas. The promoters in this case were the citizens of the State's capital, and the energy shown in the planning and completion of this mammoth enterprise proves that the North and West are not alone in keeping abreast of the times. A massive cut-granite dam 1,200 feet long by 60 feet high has been built across the Colorado River, backing it up for 28 miles and forming Lake McDonald, named after the



Mayor who served three terms of office during its construction and completion. A magnificent power house has been built, three miles from Austin, from which electric light, power, heat and the city's water supply is being constantly furnished. Already 2,000 electrical horse-power can be furnished to the wires. There is also a pumping capacity of 1,000 horse-power installed. The water supply will warrant a use of 9,000 horse-power, and the necessary penstocks and headgates are all provided. Here is an excellent opportunity for cotton manufacturers to get cheap electric power immediately in the cotton belt where labor is cheap. Great credit is due our Austin friends for the bold undertaking, as well as for its successful completion and manipulation.

At Bangor, Me., the electric lighting and power for the city has been transmitted from Veazie, Me., four miles distant, for the past five years.

The Penobscot River is turning dynamos at the latter place and over 1,000 horse-power is used for driving street cars, lighting and small power purposes. This is among our early installations and was pushed to completion by the Public Works Company, of Bangor.

Among the earlier users of water power for lighting purposes were the citizens of Rochester, N. Y. The lighting and small power is furnished from four water-power plants on the Genesee River, which passes through the city. Some of these plants have been running day and night for eight years.

At Columbia, S. C., the Columbia Cotton Mills Company have erected their factories on high land convenient for shipping, and transmit by the polyphase system about 1,500 horse-power one-quarter of a mile. This installation, as well as the following one, marks a new era in cotton manufacturing.

At Baltic, Ct., there is developed about 800 horse-power that is transmitted four and one-half miles to the factories at Taftville, Ct.

Among the earlier water-power developments in the United States is the power house of the Ithaca Street Railway Company, Ithaca, N. Y. The station sets in a pocket at the bottom and side of Fall Brook gorge. By the use of a long steel pipe two of the cataracts are made to furnish a head of 94 feet. On account of the long, closed flume of 600 feet, it was found necessary to use a stand-pipe and air chambers immediately over the two double horizontal turbines. This precaution was necessary on account of the regulation of the turbines. Here also is to be found a good example of draft-tube regulation, which was also necessary on account of the long flume or penstock. This power house furnishes 800 horse-power for lighting and power purposes in Ithaca, the seat of Cornell

University. It also propels the street cars up the steep grades to the campus overlooking Cayuga Lake. Two remarkable facts are demonstrated in this installation. The first is that heavily loaded street cars can climb long steep grades full of curves successfully, even when the grades range as steep as 12 per cent in some places and average eight per cent for one-half mile or more in others. The second fact is that they can be driven and governed successfully by water power.

At Great Falls, Montana, there is available over 200,000 horse-power that can be readily used for transmitting purposes. The Missouri River falls in cascades for a distance of 12 miles, and the separate falls range from 10 to 90 feet in height, the sum total being about 700 feet fall. There is about 10,000 horse-power developed and nearly all of it is electrical development. It is mainly used for smelting purposes by the electrolytic proc-

ess. The city is lighted electrically from the water power and the street railways are furnished current from the same source. Montana is a great copper-producing State, and here in the copper region is provided the Great Falls of the Missouri, which can be harnessed to smelt copper for use in harnessing more of the waterfalls of the world.

The Augusta Street Railway, of Augusta, Ga., was among the first in the field to drive street cars by water power. The lighting and small power of the city is also furnished electrically by water power.

At Columbus, Ga., a new and more modern electric power plant has lately been finished, and one of the finest electric railway systems in the country is furnished current from this water-power station.

Spokane, Wash., is furnished power and light from a large power house below the falls. This water-power plant is one of the earlier develop-

ments. The power units are small, but the plant is extensive. There is great opportunity for electrical development for smelting purposes at Spokane Falls.

Another interesting installation is the transmission plant of E. G. Stoiber, Silverton, Colo. Water power is harnessed and transmitted by electric current for three miles to the Silver Lake mines. Its operation and economy have been so satisfactory that the power house is being enlarged, and the water power supplemented with steam. It has been found more economical to transmit the power to the mines electrically than to haul it there in the form of fuel. An interesting feature of this private installation is that it will be the largest electric power plant in Colorado when finished.

At Sewalls Falls, N. H., great quantities of power are generated and carried by electrical transmission to Concord, four miles away, to

turn the factory wheels in that city.

At Lowell, Mass., water-electric power is transmitted 14 miles to drive street cars.

Near Nevada City, Cal., the Nevada County Electric Power Company have tapped the South Yuba River and carried the water nearly seven miles in a wooden flume to a mountain spur. Here they drop it 210 feet through their power house and transmit the power electrically from five to twelve miles to surrounding towns and mining camps. They have already installed 1,200 horse-power of wheels and dynamos.

At Redlands, Cal., the Redlands Electric Power Company have caught a mountain stream before losing itself in the plains, and have been compelling it to furnish power and light for the city for some years past. The plant is now increased to 1,000 horse-power capacity and the transmission is seven and one-half miles. The

lines will be lengthened to reach some neighboring cities.

At Hartford, Ct., 300 horse-power is transmitted 11 miles to a synchronous motor that drives the dynamos in a power station.

At Telluride, Colo., 1,000 horse-power is transmitted 15 miles electrically.

At Pelzer, S. C., the Pelzer Manufacturing Company have installed a water-power and transmitting plant to carry 5,000 horse-power three and one-half miles to factories located convenient for shipping facilities.

The St. Anthony's Falls Water Power Company, Minneapolis, Minn., are at present working on an electric water-power station of 10,000 horse-power capacity. The Pioneer Electric Company, of Ogden, Utah, are building a long transmission plant of 5,000 horse-power capacity. The Power Development Company, of Bakersfield, Cal., are installing a 1,500 horse-power transmission plant

in that vicinity. There is a 15-mile transmission at Pomona, Cal., a 13-mile transmission at Bodie, Cal., and a seven-mile transmission at Anderson, S. C., of about 150 horse-power each.

There are many more new projects under way, and there are many now in service that are not essentially long-distance transmission plants. There are many central stations that use water entirely or in part for motive power, the water being used to its limit before the steam is turned on.

It does not seem out of place to make brief mention of some of the long-distance transmitting electric water-power installations in foreign countries before closing.

First might be mentioned the Lauffen-Frankfort experiment. This was a governmental experiment in 1892, in which 200 horse-power was transmitted from the dynamos in the water-power station at Lauffen to Frankfort, 109 miles distant. Step-

up transformers were used in this installation. While the pressure at the dynamo was only 50 volts, it was raised to 40,000 volts on the transmitting line. The maximum loss between the water-wheel shaft at Lauffen and the motor shaft in Frankfort was only 28 per cent. Greater losses than this can be found in many of our finest manufacturing plants where power is carried short distances by mechanical means.

At Pachuca, Mexico, 2,000 horse-power is transmitted 23 miles. At Guadalajara, Mexico, 350 horse-power is carried 18 miles.

The city of Rome, Italy, receives 9,000 horse-power from waterfalls at Tivoli, 16 miles distant. Milan, Italy, will use 10,000 horse-power from a water power 19 miles away, and 1,000 horse-power is transmitted 18 miles from the river Gorzente to Genoa, Italy. In Sweden there is an eight-mile transmitting plant, carrying 400 horse-power into the city of Gringes-

berg, and at St. Hyacinthe, Quebec, there is a transmission of 450 horse-power a distance of five miles from the Richelieu River. Another note-worthy development in Canada is the harnessing of Montmorency Falls to supply Quebec with power and light. All of the above plants use polyphase currents.

A further evidence is the interest taken in transmission by Japan. That plucky Oriental nation is never slow to see advantages. Japan is a mountainous country. Her people are lovers of nature, but the advantages to be gained by harnessing her waterfalls have become so apparent that the government intends to develop the water powers for the advantage of the citizens. At this writing there is a commission in the United States from Japan, who are investigating power transmissions, as well as the telephone and other electrical conveniences. This commission is headed by Mr. Seirio Mine, elec-

trical engineer to the Department of Communications of the Mikado's Government, Tokyo, Japan. Mr. Mine has spent several weeks on the Pacific slope, and will visit Niagara and other propositions in the East before returning to Japan.

The adoption of electrical transmission by our wide-awake mining companies is a most telling proof of its value. By its use low-grade ores that are distant from fuel or water power can be made to yield good returns, and mines that are above the snow line can be worked as readily as if they were at the mountain's base; the distant torrent can furnish light and power for mining, as well as heat for smelting purposes. Since electric cars are rivals of the "burro" in climbing hills, we may expect to see our great mining districts supplied with transportation facilities that will help greatly toward their proper development.

The matter of propelling our rail-

way trains up the mountains by electricity and water power is being more and more discussed every day. Many heretofore valueless water powers are finding their way into the hands of shrewd business men. The world in general is becoming more aroused to the possibilities of electrical transmission, and when it appreciates fully the advantages that can be obtained by "electricity and water power," then we will have reached the full dawn of the "Electric Age."

WATER WHEELS

MANY SPECIAL BUILT STYLES, UPRIGHT AND HORIZONTAL.

Adapted in design and style to all heads

FROM 3 FEET to 2000 FEET.

TWO Wheels, 2400 H. P., Cliff Pulp Co., Niagara Falls, 125 Feet Head.
FOUR Wheels, 4800 H P., H. R. Pulp Co., Palmer's Fall, N.Y., 54 Feet Head.
FOUR Wheels, 5600 H. P., Glen Pulp Co., Berlin Falls, N. H., 46 Feet Head
FOUR Wheels, 8000 H. P., Electric Plant at Niagara Falls, 215 Feet Head.
FOUR Wheels, 1000 H. P., Mining Plant, Ward, Col., 750 Feet Head.

OUR WORK IS ADAPTED TO ALL KINDS OF

WATER POWER PLANTS

Securing a ***high guaranteed percentage*** and ***great steadiness*** of motion under variable loads. An ***unequaled concentration*** of power, and an ***unprecedented high velocity.*** Its ***quickly operating balanced gates,*** affords ***prompt and fine regulation*** by governor. Write for catalogue and state your wants.

SATISFACTION GUARANTEED
WHERE OTHERS FAIL.

JAMES LEFFEL & CO., Springfield, Ohio, U.S.A.

complex and absorbing mind

Strenuous life that has set so

most men in strenuous in

their own behalf

Learn and when knowing

to apply.